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A framework for planning sustainable development in coastal regions: An island pilot project in Croatia

Anamarija Frankic
College of William and Mary - Virginia Institute of Marine Science

A FRAMEWORK FOR PLANNING SUSTAINABLE DEVELOPMENT IN COASTAL REGIONS
An Island Pilot Project in Croatia

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Anamarija Frankic

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Maurice P. Lynch, Ph.D.
Committee Chair/Co-Advisor

Carl H. Hershner, Ph.D.
Co-Advisor

James E. Kirkley, Ph.D.

John D. Milliman, Ph.D.

Margaret A. Davidson, J.D.
Director, Coastal Services Center, NOAA
Charleston, SC

TABLE OF CONTENTS

TABLE OF CONTENTS (CONT'D)

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LIST OF FIGURES

Page

LIST OF FIGURES (CONT'D)

LIST OF TABLES

ABSTRACT

There have been few empirical studies demonstrating how sustainable development has been realized in a specific regime. This project developed and tested a framework for comprehensive planning including environmental, social, and economic considerations on the island Cres in the Croatian Coastal Zone.

The approach defines sustainable development in coastal regions, and develops a generic framework incorporating biological, geological, chemical, physical, social, and economic factors necessary for sustainable development. The generic framework ensures that planning decisions will be based on environmental concerns of the area. A prime principle of the approach is that any plan must work with the environmental limits for sustainable development. Within these limits, however, many options for environmental and social development exist. Successful resource management demands knowledge and understanding of the resources being used, the consequences of those uses, and awareness that decisions ultimately reduce remaining options. In addition, the awareness of these consequences can be used to mitigate "bad choice" decisions. The use options are based on environmental carrying capacities, and incorporate a resource-based economy in agriculture, fisheries, aquaculture, and ecotourism.

The project uses integrated Geographic Information Systems (GIS) and remote sensing technology to define existing environmental conditions, and identify resource limitations and constraints caused by potential uses, as well as environmental requirements and options for each potential use. Insufficiencies in the database that could hinder the full implementation of a comprehensive resource use plan were identified early. Using GIS, potential use conflicts were identified, and possible use scenarios in conjunction with various managements were evaluated. Finally, the GIS database was combined with current use-impact models creating an analytical tool for evaluating impacts of alternative development scenarios.

The generic resource framework for sustainable development, planning and policy development establishes a base to which political, economical, and social considerations can be added. This integrated coastal system model is intended to guide the development of rational and integrated long-term social and economical policies for the continuing use of the coastal zone.

INTRODUCTION

" The earth provides every people's need, but not every people's greed! " (Gandhi)

The mechanization of nature, our common heritage, has led to a depersonalization of the earth around us, making it easier to use and discard resources that took millions of years to develop. The practical success of science has created models that exclude most of our living experiences, often presenting only fragments of the knowledge, often in a passive way. Knowledge without behavior leaves no discernible trace of change, and behavior without knowledge will last only until the next fad. Throughout history we have attempted to develop, accomplish and define the best ways to understand, use, and protect the natural heritage around us.

Coastal systems strive to maintain an ecological balance that results in shoreline stability, beach replenishment, and nutrient generation and recycling. Human activities that contribute to pollution, habitat destruction, and exploitation of resources often threaten these systems. Historically two factors have produced a demand for Coastal Zone Management (CZM): scarcity of resources and competing values (Sorensen et al., 1984).

Coastal areas have been subject to rapidly increasing demands for urbanization, industrialization, transportation, and recreation. Poorly planned shore developments threaten vulnerable wetlands, riparian forests, estuarine ecosystems, and increase risk of natural hazards (storms, flooding, erosion) (Steffen et al. 1992). When cumulative effects of small-scale modification and major impacts of development are considered, the urgency for coastal zone management becomes obvious. These are exacerbated by socioeconomic/political demands primarily associated with the allocation among competing uses to provide the greatest social benefit.

Coastal management includes the process of resolving conflicts among a variety of coastal users, determining the most appropriate use of coastal resources, and allocating uses and resources among legitimate owners (Chua, 1993). Ultimately, management exerts actual control over people, activities, and resources.

Historically, protection of coastal zone ecosystems has been delayed by an inability to quantify environmental impacts of various types of development. In recent years, environmental impact assessment has been introduced. At present, this is primarily a subjective process hampered by a lack of quantitative techniques that could aid in establishing cumulative impacts of a project (Klose, 1980).

There are two components of CZM: planning and management. Integrated planning provides directions to sectors participating in the development process. The goal is to prepare a comprehensive plan that specifies means to effectively balance environmental protection, public use and economic development that achieves optimum benefits for all parties. The integration of activities coordinates the process of gathering, analyzing, planning, and implementing (Hildebrand, 1989).

Without proper management of all components within the ecosystem, the viability of the ecosystem is threatened. However, since there is no consensus regarding the concept of a sustainable development, no base exists for establishing criteria for attainment. Recent research targets the need for more comprehensive measures of sustainability to provide better guidance (IUCN et al. 1991).

Long-term solutions to problems are dependent upon an adequate understanding of the physical and biological processes. Lack of knowledge of the dynamic forces acting between land and water often lead to only short-term solutions (Winsemius, 1995). Short-term benefits may cause environmental instability due to fragility and vulnerability. Environmental instability is generally expressed as large fluctuations in the composition of flora and fauna, often with extinction and invasion, drastic changes in the use of resources, and demographic and economic fluctuations.

In general, the problem is that often a single-issue approach to ocean and coastal management creates overlapping and uncoordinated laws and jurisdiction, which result in conflict and increasing ineffectiveness with increasing ocean and coastal activities. There are presently no requirements within a country's coastal management plans that require local, national, regional, and global consistency in implementation, monitoring, and evaluation.

About 60 percent (3.6 billion) of the world population is already concentrated within 60 km of the coast, together with considerable migration of population to the coast from inland areas. According to the United Nations Environment Programme (UNEP, 1998), within three decades this percentage will rise to 75 (6.4 billion). Increasing human population, changing socio-economic structures, fluctuating environmental conditions, and the on-going exploitation of natural resources need an integrated, interdisciplinary management strategy founded on principles that enable long-term sustainable development.

A potential solution to the problem is to establish national guidelines for planning and managing the uses of ocean and coastal resources, and for developing Best Management Practices (BMPs) for each and every type of activity in coastal areas. This requires improved attention to environmental conditions to reduce negative impacts on coastal ecosystems. There is a need for an analytical framework and guidelines at local and national levels. This present paper uses a region in Croatia (the Island Cres) to develop and test a protocol for creating an analytical framework for Integrated Coastal Zone Management (ICZM).

Project Objectives

"Knowledge of the facts of science is not the prerogative of a small number of people, isolated in their labs, but belongs to all the people, for the realities of science are the realities of life itself." (Rachel Carson)

This study was designed to provide a framework to serve as a model for coastal zone management in the Adriatic and Mediterranean region. In doing so, it must be remembered that a world wide "coastal zone management policy" can not exist (Sherman et al. 1993).

There have been just few empirical studies related to site/specific sustainable development (e.g., Maho Bay in Virgin Islands, Dewees Island in South Carolina, SW Sulawesi in Indonesia). This project considers both development and implementation of a framework for comprehensive planning. The planning uses environmental, social and economic factors.

The project focuses on the coastal zone where variations in climate and sea level and the spectrum of human activities have a great potential for adverse environmental impact. Coastal regions are considered among the most biodiverse regions on earth (Ray, 1995). Here, a concentration of environmental and physical processes work together in a compact area (Sorensen and West, 1992).

This project first defines sustainable development for coastal regions. It then develops a generic protocol that incorporates biological, geological, chemical, physical, social, and economic factors necessary for sustainable development. Finally, the protocol is applied to the real world, with a pilot study area on the Croatian coast. A use plan for the study area is developed, based on environmental carrying capacities, incorporating a resource-based economy in agriculture, fisheries, aquaculture, and ecotourism.

Coastal zone planning must take into consideration the sustainability of the living resources of coastal systems. Ecosystems are inherent recyclers of energy, and can provide the resources humans need as long as critical processes are left undisturbed. Ecosystems, although frequently described as "fragile", have remarkable powers of resiliency. As long as basic processes are not irretrievably upset, ecosystems will continue to recycle and distribute energy. A healthy functioning ecosystem not only sustains itself, it also sustains local communities, and regional economies and resource based industries.

As a result of the increasing concentration of population pressure in coastal areas, anthropogenic impacts on the coastal zone have become severe in recent decades. Potential impacts include ecological modifications that can affect the diversity and stability of coastal ecosystems. Long-term environmental implications of the effects that these modifications may have on climate, geomorphology, and living resources are uncertain.

Development of a generic framework ensures that planning decisions would be based on environmental concerns of the area. Any process must work with the environmental limits for sustainable development. Within these limits, however, many options for environmental/social development exist. Successful resource management demands knowledge and understanding of the resources being used, the consequences of each particular use, and awareness that decisions ultimately reduce remaining options. In addition, the knowledge/awareness of these consequences can be used to mitigate "bad choice" decisions.

The proposed project uses integrated GIS (Geographic Information System) and remote sensing technology to define existing environmental conditions, and identify environmental limitations and constraints caused by potential uses, as well as environmental requirements and options for each potential use. Insufficiencies in the database that could hinder the full implementation of such a comprehensive resource use plan were identified early. Using GIS, potential use conflicts were identified, and possible use scenarios in conjunction with various management options were evaluated. Finally, this approach combined the GIS database with current use-impact models to create an analytical tool for sustainable development.

The project has two principle objectives: development of an ecological, generic framework for planning sustainable development in coastal regions; and testing of this framework by identification of specific planning option for the Croatian coast, using the Island Cres as the case study area. A generic framework for sustainable development, planning and policy development establishes a base to which economic, social, and political considerations can be added. The complete framework is intended to guide the development of rational and integrated long-term social and economic policies for the continuing use of the coastal zone.

Why islands? In general, due to their size, and location within the coastal zone area, islands present a good study areas for integrated coastal zone management because externalities involving "continental" land use can be minimized. The islands are perceived as closed systems that can become appropriate "polygons" for applied science, for implementation of scientific and technical solutions as an aspects of sustainable development. For this project the island Cres was chosen as a suitable pilot model because of abundance and availability of data (UNEP, 1996a).

History of Coastal Zone Management

In the 16th century, Grotius defined that the Common Heritage referred to the sea: "...Nature supplies every place with all the necessaries of life, and by the decree of divine justice it was brought about that one people should supply the needs of another". Four hundred years later (1967), Ambassador Pardo of Malta redefined the oceanic common heritage to include the resources of the ocean outside the areas of national jurisdiction. In 1982 The United Nations Convention on the Law of the Sea (UNCLOS) created Exclusive Economic Zone extending 200 nautical miles out from the coast. This Convention became effective in November 1994 (Clark, 1996).

The notion of unified management of the coastal zone first developed in the United States. The first apparent use of the phrase "coastal zone management" was in a 1969 report undertaken by the presidential Stratton Commission ("Our Nation and the Sea"). Ocean development was advocated by this report under the Marine Resources and Development Act of 1966 ("...the coast is, in many respects, the Nation's most valuable geographic features...") (Godschalk, 1992).

The Stratton Commission defined the primary problem of the coastal zone as a "management problem" and proposed that state coastal zone authorities be given broad powers for planning, regulation, land acquisition, and development. An important fact was the recognition that CZM was an important part of the nations' overall approach to Ocean Policy. The Commission recommended that a Coastal Zone Management Act (CZMA) became enacted.

Coastal zone management became a formal governmental activity in 1972 with the enactment by the US Congress of the Coastal Zone Management Act (CZMA). This Act provides policy objectives for the coastal zone and authorizes federal grants to facilitate the establishment of state coastal zone authorities empowered to manage the coastal water and adjacent land (Hildebrand, 1989). A number of other nations initiated coastal zone management efforts in the late 1970s and early 1980s. The terms such as coastal zone management, coastal resource management, integrated resources management, and coastal area planning and management have been used interchangeably in describing the same efforts. Many of these programs, however, have dealt with a single sector such as coastal erosion or shoreline use. Most did not attempt to deal comprehensively with the entire coastal zone and its full range resources and related problems.

The most important movement in developing this broader concept that became known as CZM was the recognition of the systemic nature of coastal resources, and the Stratton Commission first coined the term **coastal zone** as an area having unique characteristics and requiring special management. **Coastal zone** is defined as "the band of dry land and adjacent ocean space (water and submerged land) in which terrestrial processes and land uses directly affect oceanic processes and uses, and vice versa" (Ketchum, 1972). It is a dynamic area with frequently changing biological, chemical and geological attributes that include highly productive and biological diverse ecosystems that offer crucial nursery habitats for many marine species. Coastal features (coral reefs, mangrove forests, beach and dune systems) serve as critical natural defenses against storms, flooding, and erosion; and coastal ecosystems may act to moderate the impacts of pollution originating from land (e.g. wetlands absorbing excess nutrients, sediments, human waste).

The coastal zones also attract human settlements due to proximity to the ocean's living and non-living resources, marine transportation, and recreation. The seaward limit of the coastal zone can be the edge of the continental shelf, but for practical reason is defined as the 200-mile (320-km) Exclusive Economic Zone (EEZ) (*The Noordwijk Guidelines*).

In the last twenty years, Coastal Zone Management has become an important global activity. In 1972, the United Nations Environment Program (UNEP) made its Regional Seas Program a focal point for the United Nations system in dealing with the environmental aspects of marine and coastal development. The Regional Seas Program offers a strategy and framework (institutional only) within which governments can cooperate to protect the heritage of the seas (Neuman, 1985; UNEP, 1995). At present 12 regional seas programs have been created (Sorensen, 1997).

The International Geosphere-Biosphere Program (IGBP) was established in 1990, with the aim to gain a quantitative understanding of the interactive physical, chemical, and biological processes that regulate the Earth system and its capacity to support life (Steffen et al. 1992). The IGBP developed the Land-Ocean Interactions in the Coastal Zone (LOICZ) project with implementation starting in 1993.

The World Bank is participating with its Blue Team in the work of the recently launched Global Water Partnership, the establishment of a Bankwide Coastal Zone Management Network (World Bank, 1998). In 1997-1999 the Blue Team will focus on the preparation of a series of Water Resources Management Guidelines and Coastal Zone Management Good Practices.

The most complex example of international CZM planning is in the Mediterranean region where the Mediterranean Action Plan (MAP) was launched in 1975. It was initiated by the Regional Seas Program and agreed to by the Mediterranean countries through the Barcelona Convention, and for twenty years has played a leading role in stimulating coastal and ocean protection against pollution at the regional level (Vallega, 1994). It is presently facing the prospect of playing a new active role based on the adoption of the sustainable development paradigm, focusing on three subject areas:

- Assessing resource uses and resultant environmental implications;
- Establishing a conceptual and methodological framework for the sustainable development;
- Institutional implications arising from creating a policy consistent with sustainable development in the Mediterranean region (Jeftic, 1993).

After MAP's 20th Anniversary (May 1995) this plan began the transition from an environment-centered approach, consistent with the 1972 United Nations Conference on the Human Environment, to an approach aimed at sustainable development consistent with *Agenda 21*. This change will influence both the implementation of protocols and the role of the regional activity centers, primarily involving Integrated Coastal Zone Management (ICZM) (Vallega, 1994).

One of the first ICZM definitions was given at the International Coastal Zone Workshop in 1989: "ICZM is a dynamic process in which a coordinated strategy is developed and implemented for the allocation of environmental, socio-cultural, and sustainable multiple use of the coastal zone" (CAMPNET, 1989). ICZM has been identified as the most appropriate process to address current and long-term coastal management issues, including habitat loss, degradation of water quality, changes in hydrological cycles, depletion of coastal resources, adaptation to sea level rise and other impacts of global climate change (WCC, 1994, CARICOM, 1996). It differs from the earlier form of CZM in attempting a more comprehensive approach, taking into account all of the sectoral activities that affect the coastal area and its resources, and dealing with economic and social issues as well as environmental/ecological concerns (World Bank, 1996).

The ASEAN (Association of South East Asian Nations) countries' experience in coastal area management under the USAID funded and ICLARM implemented Coastal Resources Management Project (CRMP) and contributed to the sustainable ICZM (Chua and Scura, 1992). "The purpose of ICZM is to maximize the benefits provided by the coastal zone and to minimize the conflicts and harmful effects of activities upon each other" (*Noordwijk Guidelines*, World Bank, 1993). ICZM differs from the earlier form of CZM in that it attempts a more comprehensive approach, dealing with economic and social (cultural) issues as well as environmental/ecological concerns (UNCED *Agenda 21*, Chapter 17, CEC, 1992).

<u>According to Noordwijk Guidelines the ICZM principles are:</u>

- A focus on three operational objectives: strengthening sectoral management; preserving and protecting the productivity and biological diversity of coastal ecosystems; promoting rational development and sustainable utilization of coastal resources;
- Employment of a holistic perspective that recognizes the interconnections between coastal systems and uses;
- Maintaining a balance between protection of valuable ecosystems and development of coast-dependent economies;
- Promoting of an awareness at all levels of government and community about the concepts of sustainable development and the significance of environmental protection; it is proactive, incorporating a development planning element.

The term **sustainable development** implies the conscientious management of natural resources upon which all types of utilization depend, so that these resources and associated issues may be sustained over time. As it is not self-regulating, it must be planned, regulated and managed by each community and government. The Brundtland Report (WCDE, 1987) defined sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs. The concepts of sustainable development does imply limits - not absolute limits, but limitations imposed by the present state of technology and social organization on environmental resources and the ability of the biosphere to absorb the effects of human activities".

In developing an analytical framework for the ICZM, we also have to consider the following concepts: stability and carrying capacity. **Stability** is the system's capacity to absorb changes in state variables and parameters, persisting in a globally stable, dynamic regime, far from equilibrium (Holling, 1976). It considers the maintenance of basic ecological processes or the sustainable use of species and ecosystems (Kenchington and Agardy, 1990).

Carrying capacity of the resources describes the operational dimension of the life-support environment, mostly used in tourism and ecotourism activities (PAP/RAC, 1997). It refers to the size of population, human and other species that a given environment can support. Other terms such as maximum sustainable yield, and limits of acceptable change have been used to determine the limits of sustainability (Clark, 1996). Carrying-capacity modeling often has been inappropriately used to address the problem of managing resources at an appropriate level of utilization. Models often oversimplify and manipulate the relationship between environmental uses and impacts.

Ryan (1991) uses a more contemporary concept: "Sustainable capacity", which recognizes that for every environmental regime there is an appropriate range of sustainable use. All types and levels of use that can be sustained in any given management area will depend on the management philosophy and objectives specific to the resources of that area.

The Island/Coast Area Approach

The first and basic principle used in this study is that ***the environment sets the limits*** for each and any type of management/use approach (Fig.1. General Concept for Sustainable Development).

The general steps used in this approach consisted of a(n):

1. Resource assessment: Inventories of island/coastal resources
2. Impact assessment: Coastal vulnerability and risk assessment
3. Policy establishment
4. Evaluation of economic and regulatory measures
5. Implementation
6. Monitoring

(The two first steps were developed and implemented in this project.)

1. Resource Assessment

An inventory of island/coastal resources and use is the first step for a successful CZM program. To enhance resource development capabilities the country should acquire and maintain a comprehensive inventory of the physical and biological resources of coastal area as well as their uses and users. This inventory will provide a database for making decisions about long-term goals, such as ecosystem preservation, that might conflict with immediate development such as tourism or aquaculture. This first step is necessary for assessing the coastal zone vulnerability from various activity impacts, and it provides one of the basic requirements for the development of a coastal management program.

An inventory of coastal resources and uses involves activities such as:

- Identification of physical and biological data for natural and human resources in coastal areas
- Classification and assessment of coastal resources and uses in detail
- Development of sensitivity maps for coastal and marine resources and uses
- Integration of existing records and remote sensing tools for rapid, cost-effective inventories
- Identification of physical and biological standards and criteria to evaluate environmental conditions and to design appropriate environmental monitoring programs.

The "Country" should provide the resource inventory and information base that includes information on the "developable" sites; so, both local communities and developers can have the most possible complete picture on environmental conditions. As an initial part of CZM programs, monitoring and assessment information for key coastal areas should be catalogued and assembled in one place to provide a baseline for development proposals and construction impacts monitoring. The established database should be accessible to public, and shared information products should serve the needs of different constituencies.

2. Impact Assessment

The impact assessment answers the question: What will this project (activity) do to the environment?

The environmental impact assessment includes activities that will:

- compile the previous step of physical and biological data of the resources in coastal areas, with data on flooding and erosion and other potential hazards
- build a vulnerability assessment model to facilitate continuous monitoring and analysis of natural and man-made impacts
- design appropriate environmental programs to test environmental impact predictions

- develop technical, social, economical options (alternatives) that contribute to impact reduction/mitigation.

In an assessment of alternatives, decision-makers should be provided with information on how each option compares in respect to the relative costs and benefits for each impact (Sorensen and West, 1992). Adaptive assessment integrates environmental with economic and social understanding at the beginning of the project design, during the design phase and after implementation (Holling, 1976). Impact assessment can resolve conflicts among stakeholders with different interests. Identification of the full range of reasonable alternatives to resolve a conflict among competing interests means that no feasible options for maximizing benefits and minimizing costs have been missed. This information has to be provided in a useful form to the decision-makers and stakeholders.

Impact assessment should be incorporated in each phase of coastal development projects. It is important that environmental impact assessment does not try to cover too many topics or be too detailed, but rather focus on the main issues. It has to present clear options for the mitigation of impacts and for sound environmental management, considering planning and implementation of the projects.

The impact assessment should be based on best available knowledge and provide timely technical consult to environmental decision makers while acknowledging uncertainties. A general strategy that uses computer tools for assessing land-use impacts on natural resources has not yet been published, although, GIS has proved to be a successful tool in the Environmental Impact Assessment process.

There is no scientific or ecological imperative in impact assessment, it is only a tool to help making decisions and evaluate options. Nevertheless, the most important development in environmental decision process in the last decade has been the inclusion of environmental impact assessment by regulatory managers in decision-making (Power and Adams, 1997).

3. Policy Framework

The policy statement should declare the intention of a state/nation to review and regulate developmental activities affecting the sustainable use of the coastal renewable natural resources (PAP, 1996). The country has to determine the use and allocation of coastal resources based on the country's consistency provision which is based on the planning goals and acknowledged comprehensive plans (Oregon CMP, 1997).

Formulation of a policy framework for coastal and marine management must address cross-sectoral issues that infringe on coastal resource management and national development planning. The basic approach is to review and analyze existing institutional and legal mechanisms (including regulations) for integrated coastal and marine management. Based on this review, the country should propose a generic institutional and legislative framework to address coastal issues and encourage an integrated coastal zone management plan. Through a series of application scenarios, the policy framework will become a basic tool for training and education of decision-makers, resource managers, scientists, stakeholders, and public in general.

4. Economic Evaluation

Economic evaluation is an important component of a systematic assessment of coastal resources as it provides an economic framework from which differing adaptation strategies (solutions) can be studied (GEF, 1996). It is necessary to diagnose existing economic, legal, and institutional incentives that affect natural resources and the development and location of economic activities in coastal areas.

An economic evaluation should include the following components:

- quantification of each specific asset or resource
- economic valuations of assets and resources

- analysis and quantification of existing problems of depletion/degradation
- design of cost-effective adaptation strategies, potential option-scenarios
- propose incentives and insurance;

The economic evaluation should be able to justify that achieving the coastal zone management objectives will generate a net socioeconomic benefit in a long run in the most cost-effective manner (Sorensen, 1997). It also can establish minimum-cost economic and regulatory measures to apply to implementing an adaptation strategy.

5. Implementation

The success of a coastal management plan is based on the country's ability to understand how an effectively established program manages natural and human coastal resources. It is necessary to establish monitoring and evaluation of land use decisions and changes in coastal resources as well as in their integral uses. The consideration of alternative options provides a basis for choosing the best action rather than determining whether the proposed action is acceptable (O'Brien, 1995).

Implementation strategy: or how to apply science?

> Best Management Practices (BMPs): "A practice or combination of practices that are determined to be the most effective and practical (including technological, economic, and institutional considerations) means of controlling point and non-point pollutant levels compatible with environmental quality goals" (Virginia Department of Environmental Quality, 1995).

Good examples of using BMPs in implementation and management of resources were described in the Caribbean Coastal Tourism Project (Potter, 1996). Comprehensive BMPs should become a living document, open to revisions and expansions. Established BMPs would provide consistent national standards and practices for implementation of different types of activities in the coastal region. They would provide constant monitoring and control of various activities, strengthening environmental protection and sustainable development in the coastal areas. Industries, agencies, environmental organization have recognized the need for BMPs.

BMPs for site planning and for ICZM practices provide the opportunities for early intervention and collaborative review of new activities. By publishing public standards and goals in advance of the submission of plans by a private developer, for example, one can provide guidance before major investments are made in site development. These standards (local, national, and international) also provide objective measures (criteria) that can be used by communities and environmental NGOs to question specific elements of development proposals. In general, the initiative established on governmental level would provide legislative guidance for country's regulatory agencies to adopt and implement BMPs in management plans and long-term decision making processes.

6. Monitoring

Monitoring includes the acquisition, management, synthesis, interpretation, and analysis of data with an emphasis on temporal and spatial scales. Monitoring should be well coupled with research programs designed to improve the appropriateness of routine measurements and allow interpretations of the implications of monitoring results (NAS, 1990).

Monitoring as a component of an environmental management system is defined as a range of activities needed to provide management information about environmental conditions or contaminants. A monitoring system should be integrated and coordinated with the specified goal of producing predefined management information: it is a sensory component of environmental management. A useful monitoring program provides mechanisms to ensure that knowledge is used to convert data collected into useful information.

The purpose for monitoring the implementation of a coastal management program is to assure that the major policies (goals, comprehensive plans, and agency authorities) are properly implemented. Monitoring will assess the cumulative effects of changes and assure that management program elements are updated to reflect changing needs and circumstances, but consistent with its basic requirements. This approach will provide a basis for a general evaluation of the program's success or failure in achieving its overall objectives of balanced development and resource protection and conservation (Oregon CMP, 1997).

CASE STUDY SETTING

The Republic of Croatia - Country Profile

Natural Resource Governance

Conservation and use of natural and cultural wealth are controlled by the Parliament of Croatia and people directly, in accordance with the Constitution and the legislature. The Constitution of the Republic of Croatia, Article 3 reads: "Freedom, equal rights, national equality, peace, social justice, respect for human rights, inviolability of ownership, conservation of nature and the human environment, the rule of law and a democratic multiparty system are the highest values of the constitutional order of the Republic of Croatia." Article 69 of the Croatian Constitution says: "Everyone shall have the right to a healthy life. The Republic shall ensure citizens the right to a healthy environment. Citizens, environment, public and economic bodies and associations shall be bound, within their powers and activities, to pay special attention to the protection of human health, nature, and the human environment."

Based on the Constitution and the Rio Declaration, in 1992 the Croatian Parliament passed "Declaration on Environmental Protection in the Republic of Croatia", which established the basic principles of Croatian environmental law. The Declaration was followed by the Nature Protection Act, Fiscal Planning Act, and Environmental Protection Act, all in 1994. On February 28, 1997, the Croatian Parliament adopted the National Program on Sustainable Island Development.

New environmental laws include contemporary and substantial environmental law mechanisms such as an environmental impact assessment, the right-to-know principle, the polluter-pays principle, public participation in decision making process, mitigation, sustainable-development principle and others. The enforcement measures are provided mostly within constitutional, civil, criminal, and administrative law provisions. However, the practice of environmental law enforcement does not follow these standards on a declarative level. One of the reasons for lack of enforcement is that there is only a weak tradition of environmental litigation in Croatia, and it takes a while before newly adopted environmental laws become common legal practice.

Inconsistency of laws and enforcement creates conflicts in implementation, and even more important for Croatian environmental law is that Environment Protection Act does not set any standards, terms, or conditions for public participation. Even though many highly valuable natural areas are still well preserved and deserve proper recognition and other adequate protection in accordance with the sustainable development principle, the management should be more dedicated to education, scientific research and applied science as it should be.

More than ever, the battle for the environment in post communist countries appears to be a race between unrestricted development and desperate attempts to save what still can be saved. Croatia is currently facing the threat that some of its most precious areas, in particular marine environments, are objects of uncontrolled development that ignores both the environment and respect for natural heritage. Although, the Croatian economy, exhausted by the five-year of war, has neither money nor time for expensive experiments, we should not repeat the previous and past mistakes, when unrestricted development resulted in regret and overwhelming losses.

Current deficiencies in the Croatian Natural Resource Management:

- A Ministry of Environment is not established.
- No National Sustainable Development Coordination Mechanism has been established.

National priorities and potential projects:

- **Air Quality**: Achieving the Category I of the Air Quality (clean or slightly polluted air) in the entire state territory within the next ten years.

- **Land Management**: Soil conservation against erosion, protection and management of water resources. To conduct an assessment of land use management policies and provide a comprehensive evaluation of the forest and agricultural sectors that can help stabilize Croatia greenhouses gases emissions and achieve better air quality.

- **Reforestation**: Forest fire suppression, forest soil conservation and restoration, and achieving carbon sequestration through forestry ventures.
  Forest ecosystems represent an important opportunity to conserve and sequester carbon because of their large accumulation of woody biomass. Similarly, **agricultural systems**, which cover vast acreage in Croatia, can be managed on yearly basis to augment the large store of carbon in their soils.

- **Agriculture**: Providing support for private family farms based on sustainable agriculture, based on "The Strategy of Sustainable Agricultural Development in the Republic of Croatia" (Ministry of Agriculture and Forestry).

- **Biodiversity**: Establishing the basic national legislative framework for conservation and sustainable use of biological diversity is Constitution of the Republic of Croatia (1992), which promotes preservation on nature and human environment as the highest values of the State.

- **Energy**: Developing and implementing energy efficiency measures in Croatia. By increasing energy efficiency through the application of a selected set of measures and technologies, Croatia has a possibility to implement a set of mitigation measures that would represent a significant step toward meeting the obligations and goals of the United Nations Framework Convention on Climate Change (UNFCCC).

- **Marine ecosystems and sustainable island development:** Protecting the sea and coastal areas with rational use of the natural resources. Developing and implementing the Integrated Coastal Zone Management (ICZM) Plan, which will incorporate the National Priorities.

The national priorities were considered in the development of the generic framework in the Island Cres Pilot Project.

METHODS

GIS/Remote Sensing Applications

Geographic Information System (GIS) and Image Processing techniques were used almost exclusively to develop the models. The GIS software, *ArcInfo* version 7.1.2, developed by the Environmental Systems Research Institute, Inc. (ESRI), was run on a networked Unix Platform. This software and system were implemented for all projects GIS needs. The image processing software, ERDAS *Imagine*, version 8.3, also running on a networked Unix platform, was used for all image-processing application.

Introduction:

The GIS is a sophisticated tool widely used by decision-makers. It has the ability to incorporate a wide variety of alphanumeric and graphic data, including remotely sensed imagery. Numerous definitions exist for GIS, some refer to manual and automated approaches for handling information, and others use a more restricted definition that includes computerized approaches.

GIS is an analytical tool that identifies the spatial relationship between geographically represented features and their subsequent attribute information. *ArcInfo* is a two-part database where *Arc* builds the geographic features and topology, and the *Info* component manages data associated with those mapped features (ESRI, 1995).

The U.S. Federal Interagency Coordinating Committee on Digital Cartography (1988) describes GIS as "a system of computer hardware, software and procedures designed to support the capture, management, manipulation, analysis... and display of spatially referenced data for solving complex planning and management problems". GISs store, analyze and display information according to a spatial or geographic reference. The use of GIS as a tool for land-based resource management and planning is becoming well established, but GIS applications in coastal and aquatic environments are less well defined (Ricketts, 1992).

In situ data, remote sensing data, and data generated through numerical models all can be evaluated and illustrated with GIS (Fig.13). To improve scientific understanding, and develop linkages between coastal and submerged habitats with adjacent uplands, data input to GIS models must be multidisciplinary in nature and temporally sensitive to capture shifts and responses of living resources.

I. Building and creating a digital database

<u>Database procedure:</u>

- *identification of key indicators of existing conditions to the present state of the island's environment (environmental assessment)*
- identification of island's resources under stress or at risk (impact assessment)
- identification of areas of opportunity, using site suitability and exclusion criteria
- simulation and testing of alternative options
- exploration of available information and alternative scenarios through interaction tool with query capability (integrated GIS);

For the purpose of this project, a digital database for the study area (the island Cres pilot project) was designed and built (Table 2). Database design depended on availability of data, and required preliminary research to determine what source of data could be incorporated. This process included development of a database specific to the project objectives and development of two protocols as an application system that also can be used in different projects. Initially, all data layers were identified as a component of a generic framework, which could be applied to other areas.

This approach used only available data in creating both protocols but identified any missing elements in the database design. In creating protocols targeted efforts were based on environmental benefits, available data and current understanding (C. Hershner, 1998 oral comm.).

Spatially Explicit Data Layers

The first step in the environmental assessment approach was to compile spatially explicit data layers that described the physical and biological environment of the island. Layers, referred as coverages in *ArcInfo*, included:

a) Land cover

- vegetation, geology, lithology, topography, hydrology (Figs.12, 4, 11, 14),
- shoreline, bathymetry, seabottom geology, benthic communities, coastal flora and fauna (Figs. 15, 9, 7);

b) Land use

- infrastructure facilities (settlements, roads, ports), fisheries, agriculture, tourism, mining and quarries, port-shipyard, hunting (Figs. 16, 10, 5);

Principal GIS layers developed for the project included: coastline, island boundaries, topography, internal land coverage, and bathymetry. These were created by digitizing various features from the:

1. Topographic map of Cres (1:100,000), (Vojnogeografski Institut SR Hrvatska, 1983)
2. Bathymetry map of Rijeka-Kvarneric (1:100,000), (Hidrografski Institut Jugoslavenske Ratne Mornarice, 1986).

All spatial data were referenced to a 2-D Cartesian coordinate system. Each digitized data element was stored as a separate coverage. This complete body of data for the geographical study area, the island, became a *cartographic model* comprised of map layers with geographically referenced set of data. Each layer was a two-dimensional image on which every location is associated with one characteristic (in raster-based system it is an individual grid cell-pixel, and in vector based system it is a single point-node).

GIS models were generated for the study area using the baseline coverages combined with two- and three-dimensional model algorithms that were developed using several programming modules within *ArcInfo*. These modules used a combination of planar polygons, vectors and nodes in conjunction with three-dimensional grids or pixels as their building blocks.

A model of the island was constructed using the Digital Terrain Modeling (DTM) data structure TIN (Triangulated Irregular Network). TIN is a set of adjacent, nonoverlapping triangles computed from irregularly spaced points with x, y coordinates and z values (ESRI, 1995). The TIN software package consists of specialized *Arc* and *Arcplot* commands and AMLs that are completely integrated with the entire *ArcInfo* GIS.

In order to construct a comprehensive DTM it was necessary to establish the topological relations between data elements, in this case topographic and bathymetric, as well as an interpolation model to approximate the surface behavior (Weibel and Heller, 1991). This approach allowed a presentation of assembled and analyzed data, combining DTM with digitized coverages in an overlay analysis. Finally, spatial modeling, an advanced form of overlay analysis, was used to generate maps (models) from existing maps and the attribute database in response to GIS queries using the constructed database.

The *ArcInfo* surface analysis function (CREATETIN) was used to create TINs from topography contour data set and elevation points, and bathymetry contour data set and depth points. CREATETIN uses the Delaunay method for triangulation (ESRI, 1995). The topology and bathymetry of a TIN was defined by maintaining information defining each triangle's nodes, edge numbers and type, and adjacency to other triangles. For each triangle, TIN recorded: the triangle number, the numbers of each adjacent triangle, the three nodes defining the triangle, the x, y coordinates of each node, the surface z value of each node, and the edge type of each triangle edge ("soft" was used as default, ArcInfo 7.1.2).

The surface value was obtained by intersecting a vertical line with the plane defined by three nodes of the triangle. The generalized equation for Linear interpolation of a point (**x**, **y**, **z**) in a triangle facet was:

$$Ax + By + Cz + D = 0$$

Here A, B, C, and D were constants determined by the coordinates of the triangle's three nodes.

Linear interpolation was used because of quicker calculations and more predictable results than with the Quintic interpolation algorithm that uses a bivariate fifth-degree polynomial in x and y (*ArcInfo* Version 7.1.2). Also, due to available georeferenced data, this function enabled better presentation and more accurate calculations of integrated data.

In creating TINs in this project, two tolerances were used to limit the processing of excess data:

- *Proximal tolerance* - the minimum distance in ground units separating all point locations on the horizontal plane (data digitized from the charts); and
- *Weed tolerance* - the minimum allowable tolerance between any two vertices along the arc. This is the distance in ground units used to reduce the number vertices along individual arcs, creating mass points for project needs. By weeding the existing elevation contour data set and the bathimetry data set, the tolerance was expressed with the Douglas-Pencker algorithm (ESRI, 1995).

Island TINs were presented by the *ArcView* with 3D Analyst (Fig. 17).

Example from the project:

CREATETIN *beachtin* 120 60 (*)

Cover *beach* lines beach mass

cover *topline* lines top mass

cover *peak* points top mass

cover *testbat* points bat mass

(*) The values for weed and proximal distance were based on distances between contour lines and between points data sets for elevation and bathimetry. The average value was 250 meters apart, and one half (rounded to the nearest 10) was taken as a value for weed tolerance (120 m). This process is called "weeding" of the arcs (contour lines). One half of the weed tolerance value was taken to express a proximal distance between points (60 m). This ratio was a good one to start making tins (1:1/2:1/4). The z values can be expressed later when creating lattice and grids, using *Arcplot* surface commands.

Mass points, each with the x, y location and a z value, were the basic elements used to build TINs in this project.

Information integration

Bringing together spatial data from number of sources (maps, field surveys, satellite image) within a single system by using consistent topological framework is called Information *integration* (Shepherd, 1991). This includes inter-conversion of image and vector models of the island within unified software framework. Integration of non-spatial data (attribute, descriptive data) with spatial information was done by using two approaches:

1. A composite map model based on the grid-cell tessellation, where the principal Integration mechanism is a map modeling capability that relates together two or more grid cell layers to produce a new layer.
2. A geo-relation model associated with the arc/node topological model of the island. Integration by spatial search and overlay of coverages, where spatial data are represented using a topological spatial data model (ARC-program), and attribute data are stored in the tables of standard relational database (INFO-program).

In both approaches the links were established between attribute information and spatial features (Shepherd, 1991).

Remote sensing

Introduction

Remote sensing, as used in this paper, is the collection of natural resources information-using imagery acquired from aircraft (aerial photography) or spacecraft (satellite imagery). Interpretation variables include color, tone, brightness, shape, texture, pattern, shadow, size, and juxtaposition. Satellite imagery provides information with a fixed pixel resolution. This resolution determines the ability to resolve landscape features like land cover, vegetation condition, water bodies, forest clear cuts, roads, and infrastructures.

Remote sensing system considerations include:

1. Temporal resolution
2. Spatial resolution and look angle
3. Spectral resolution

The multi-band radiometers of Landsat were designed primarily for land application, but their images of coastlines provide information on shallow-water bathimetry for coastal management. An inexpensive, available Landsat TM (Thematic Mapper) image was used (Landsat, 1985). TM records in six relatively narrow optical bands and one broad thermal band with a spatial resolution of 25x25 meters (usually 30x30m), and with the Mercator Map Projection. TM is currently the primary sensor recommended for coastal analysis program and change analysis for all land cover except aquatic beds.

A hierarchical classification system of the coastal land-cover and the island's upland, reflecting ecological relationships and focused on land-cover classes that could be discriminated from satellite remote sensor data was developed. Categories of the classification system were represented as two-dimensional features at the mapping scale of 1:100 000, with features mapped as lines, points, and polygons.

Standard supervised and unsupervised classification techniques have been available for more than 20 years (Jensen, 1994). In the *supervised classification* the classifier extracts mean and covariance statistics for known phenomena on a single date of remotely sensed data. These statistical patterns are then passed to a "minimum distance to means" algorithm in which unknown pixels are assigned to the nearest class in n-dimensional feature space. Or they were passed to a "maximum classification" algorithm that assigns an unknown pixel to the class in which it has the highest probability of being a member (Mansel et al. 1990). Basically, in supervised classification pixels are assigned to ground information classes through a discriminate function based on observed spectral properties of the information classes in a set of selected training sites.

Supervised classification of the Landsat TM image of the island was performed to distinguish and classify the shoreline and compare it with digitized shoreline data from the topographic map (Fig. 18). A subset view of TM with the AOI (area of interest) was used to perform GIS shoreline delineation (H.Berquist, 1998 personal comm.). TM band 4 with a wavelength of 0.76 – 0.9 micrometers was used for detecting the water-land interfaces. The tidal variation (approximately 80cm) was not considered in this measurement. This shoreline was compared with the shoreline coverage digitized from the topographic map, 1:100000. This approach indicated an achieved accuracy of 25 meters resolution, and possibility of tracking shoreline changes within those limits.

Unsupervised classification of the Landsat TM image also was performed (Fig. 17). This involved clustering individual pixels into spectral classes based on measured reflectance values in the original channels or transformations of those channels. The spectral classes were then assigned to ground information classes (land-use/land-cover categories), based on field observations, cartographic maps, and literature review or interpolations of air photos (Davis, and Simonett, 1991). The final step was the transfer of the classified image from the remote sensing software (ERDAS) to *ArcInfo* (via the Grid module) to provide a geo-referenced resource map (landuse/landcover map).

II. Geographic/Spatial Analysis

Introduction

Spatial analysis is the process of modeling and interpreting model results by extracting or creating new information about a set of geographic features (ESRI, 1995). It is a useful tool for evaluation of suitability and capability, for estimation, and for interpretation and understanding of data and processes. In GIS there are four types of spatial analysis: spatial overlay, surface analysis, linear analysis, and raster analysis, and they all were used in this project.

Spatial analysis was performed to identify sites for suitable aquaculture and ecotourism based on established criteria (requirements). Spatial modeling is an analytical procedure, part of spatial analysis, applied with a GIS. For the purpose of this project, two categories of spatial modeling functions were applied to geographic data:

1. Geometric model with generated buffers: A buffer is a zone of a specified distance around coverage features.
2. Polygon overlay or coincidence model: GIS overlay analysis can be described by mathematical equation:

$$\mathbf{b}_{xy} = \mathbf{a} + \mathbf{c}\mathbf{M}_{xy} + \mathbf{d}\mathbf{N}_{xy} + \mathbf{e}\mathbf{O}_{xy}$$

- where some value **b** with coordinates **xy** is related to several factors each of which is a map layer (**M**,**N**, and **O**) with coefficients **a**, **c**, **d** and e;

- combining them we create a new map showing computed value **b** at every site on the map.

Those two model categories were used to support analytical performances on geographic data objects (points, lines, polygons, tins) creating alternative scenarios.

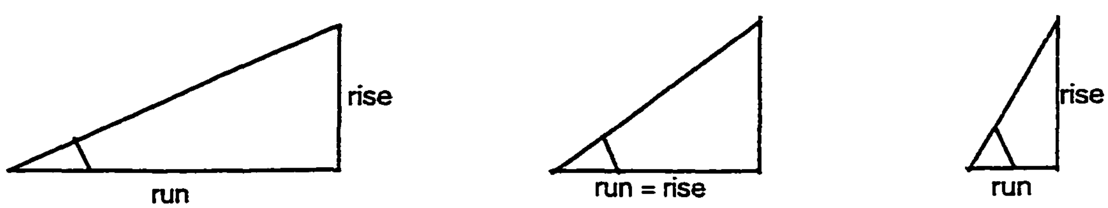
Slope

Slope is the first vertical derivative of elevation (Carter, 1992). It is an abiotic factor that influences numerous ecological phenomena. Slope refers to the angle of inclination of a land surface above horizontal. Slope steepness can be calculated by many formulae (Chang and Tsai, 1991). The accuracy of each method varies and depends on the quality and scale of the basic DEM. Generally, as DEM raster or scale size increases the slope accuracy decreases.

ArcInfo uses a command TINARC that calculates slope from the DEM generated TINs. This can be expressed as either percent slope or degree slope. I used degree slope calculated by TINARC in my spatial analysis because the geo-referenced data available did not have resolution required by other formulae.

Mathematical expressions for the slope steepness:

Degree slope = θ	Percent slope = %
Rise/Run = $\tan\theta$	Rise/Run x 100



Degree slope = 30°	45°	75°
Percent slope = 58%	100%	370%

With TINARC command the percent slope calculations were computed in percent slope (with a range from 0 to infinity):

- the average value for the Island was 20%, maximum = 645%, and minimum = 0%.

Degree slope calculations were computed in degrees (with a range from 0 to 90°):

- the average value for the Island was 10°, with maximum of 81°, and minimum of 0°.

AQUACULTURE PROTOCOL

(Past activity and potential future activity on the island)

Introduction and Definition:

> "Aquaculture is the farming of aquatic organisms, including fish, mollusks, crustaceans, and aquatic plants. Farming implies some form of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators" (FAO, 1990).
>
> Aquaculture is the "propagation and rearing of aquatic organisms in controlled or selected environments" (National Aquaculture Act. 16 U.S.C. 2801 et seq.).

In the Adriatic Sea, the majority of cultured marine fish species are grown in cages. These are square, floating frames of surface area 8 - 50 m^2 with nets suspended into the water column to contain the fish (PAP, 1996). In order to maintain ecological stability of the used ecosystem, polyculture of fish with shellfish species is practiced and recommended (Shpigel et al., 1993). In polyculture systems a proper combination of ecologically different species at adequate densities utilize the available resources efficiently by maximizing the synergistic relationships between species and the environment, and minimizing the antagonistic ones (Milstein, 1992).

According to present trends and experiences in the Adriatic and north Mediterranean, shellfish mariculture would consider oysters (*Ostrea edulis* L.), and Mediterranean mussel (*Mytilus galloprovincialis* Lam.) (Hrs-Brenko and Filic, 1973). Fish farming in floating cages would include sea bass (*Dicentrarchus labrax* L.), and gilthead bream (*Sparus sparus* L.) (Filic, 1978).

This part of the project dealt with aquaculture activity in the coastal area and its specific requirements regarding cage farming of native species of fish and shellfish in the Adriatic Sea (Table 3.) (Goldburg and Triplett, 1997). The main objective was to determine and define environmental suitability parameters required for potential aquaculture sites.

Aquaculture sites have requirements for space on water and land. The carrying capacity for aquaculture is defined as the maximum number of users (marine species) that can be supported by a natural or man-made resource without producing negative environmental consequences to their future activity, productivity and quality.

Capacity assessment of a site (UNEP, 1987):

- to consider contribution from all major sources of organic loading without any negative influence on the surrounding environment
- to evaluate capacity without nontrophic resources that can cause eutrophication, oxygen depletion
- to calculate capacity in terms of organic waste, sediment fauna monitoring, the levels of production are usually converted to production as tones per km^2 (Costa-Pierce, 1994);

Determination of suitability involves an evaluation of natural and anthropogenic limitations of a certain area in order to decide if the locality can support the activity.

Suitability analysis/Environmental limitations

The initial phase of a suitability evaluation includes an environmental evaluation by classifying current conditions, identification of existing and possible future constraints, compatibilities and incompatibilities between the main resources and human activities (PAP/RAC, 1996).

Types of suitable environments:

1. Lagoons - for extensive aquaculture (low density organisms, depend on natural food)
2. Estuaries - for semi-extensive aquaculture
3. Coastal sheltered zones (bays, channels) - for intensive aquaculture (high-density organisms, artificial feed)

Site identification considered the following existing conditions based on available data and established criteria (modified from UNEP, 1987):

1. Environmental conditions

Natural Resources:

- geomorphological (slope) and physical (currents, tides) characteristics of the coastal area, bottom substrate, freshwater streams, submarine springs (Hrs-Brenko and Igic, 1968, Hrs-Brenko, 1974) (Table 3.)
- climate (temperature, wind, precipitation)
- physical, biological, chemical characteristics of marine ecosystems: temperature, salinity, pH, BOD, COD, transparency, turbidity, marine species, phytoplankton and zooplankton biomass, pathogens, fecal coliform (Kator, 1993; Kator and Rhodes, 1994; EPA, 1996) (Table 3.)

Human Resources

- existing use(s) of the area
- anthropological impacts, urban pollution (sewage system)
- agriculture and impacts
- fisheries and possible conflicts
- industry
- tourism
- energy and water supply

2. Physical accessibility

- infrastructure (roads) (Tables 3 and 4)
- communication dependence on land and by waterways

3. Other conditions

- other existing or potential "uses" of the same area such as nature reserves, marine sanctuaries, protected species, SAV, migratory pathways, etc.

<u>**Use Interactions/Conflicts:**</u>

(Tables 7 and 9)

1. Aquaculture – Environment

Potential impacts of aquaculture activity consider modification of water quality, alternation of water dynamics, environmental impacts if foreign species are introduced, diseases, etc.

2. Aquaculture – Fisheries

The conflicts between two uses consider space competition and economic competition.

3. Aquaculture – Agriculture

It would be beneficial to promote sustainable integration of both when agricultural by-product can be effectively used for aquaculture (under control). Otherwise, the use interaction causes a space competition.

4. Aquaculture – Tourism

The use conflict in this case considers space competition with beach areas, even though aquaculture in general supports tourism activities.

5. Aquaculture – Mining

Mining activities cause modification of water quality, and increase a potential effect of erosion.

6. Aquaculture – Ports (Marinas)

The use interaction considers space competition, and water quality issues.

7. Aquaculture - Sewage system

There is a spatial use conflict, and water quality issue-conflict.

8. Aquaculture - Reserve sites

Those two uses can not co-exist in the same place.

The general protocol for aquaculture is presented in the Table 3. Due to lack of spatially explicit data for required parameters for environmental suitability analysis, it was necessary to modify aquaculture protocol in order to apply it in this project (Table 4).

ECOTOURISM PROTOCOL

(Existing activity and potential future development)

Introduction and Definition:

> The Ecotourism Society (1991) defines an ecotourism as "purposeful travel to natural areas to understand the culture and natural history of the environment, taking care not to alter the integrity of the ecosystem, and producing economic opportunities that make the conservation of natural resources beneficial to local people."

Increases in tourism have brought many coastal regions to a threshold at which the experiential satisfaction of the tourist and economic satisfaction of the investors begin to decline due to degradation of the environment (Frankic and Lynch, 1996). Ecotourism has captured a special niche in the overall tourism industry because many people care about and are concerned with the natural world.

Ecotourism was established with good intentions and in the main tries to be environmentally sensitive. But the "good" feeling or experience gained by people engaged in ecotourism does not necessarily mean that "nature" experience "good". In many instances ecotourism can have the same negative results and adverse impacts on the environment as tourism in general. The evaluation of impacts involves scientific assessment of each area affected by the tourism activity. Hotels and other tourism-related infrastructure will benefit economically and ecologically by supporting long-term resource management solutions. Competition within tourism will now be based on the quality of the environment and preservation of the environment as well as for human creature comforts.

Ecotourism should combine ecology and tourism in an educational experience together with preservation of the visited environment. To achieve successful ecotourism and establish sustainable development within coastal regions it is necessary that ecotourism planning becomes the leading tool for promoting environmental protection and preservation.

Ecotourism enterprises have little hard scientifically based criteria against which potential positive, neutral or negative impact on the resources can be measured. The philosophical and conceptual models of social and economic dynamics that form the basis of most current decision making, fail to account for the spatial, temporal and cultural heterogeneity that characterizes the real world of natural resource management (Brandon, 1996).

Suitability analysis/Environmental limitations

The principles and criteria for sustainable ecotourism development must be based on national and international standards for physical, chemical, and biological indicators of an ecosystem's air, land, and water condition. Qualitative and quantitative parameters include parameters such as biological oxygen demand (BOD), chemical oxygen demand (COD), CO_2, coliforms, heavy metals, pH, salinity, rainfall, hydrography, biodiversity, etc.

What is a potential beach areas' carrying capacity?
The European standard for the beach carrying capacity is 6.8 m^2/swimmer (PAP, 1993). Japan International Cooperation Agency recommended a limit of 200 rooms/km of beach for good environmental conditions for tourism in Southern Thailand (Wong, 1998). In Croatia the beach capacity has been estimated as 6 m^2/person (Urbanisticki Plan, 1991).

How many people can optimally use the island beaches?
Considering the mostly rocky Croatian shoreline with only a few sandy beaches, an average beach area per person was estimated to be 10m^2 for this project.

What is a healthy beach for swimming?
Coliform bacteria as an indicator of human fecal contamination has been used effectively as

a health measure in controlling beach areas for recreation, aquaculture activities, and sewage treatment technologies (Kator and Rhodes, 1994; Geldreich, 1977; Keckes, 1972). The US EPA has established the criteria for bathing in marine waters. The geometric mean of the indicated bacterial densities should not exceed for *E.coli* 126/100ml, and for *Enterococci* (EN) 35/100mL. In Thailand the total coliform standard for bathing water is 1000 MPN/100ml (Wong, 1998; EPA, 1996).

Croatia has classified the quality of the coastal waters based on the concentration of total coliform (SFRJ, 1978 in the Urbanisticki Plan, 1991) as:

I Category - waters suitable for aquaculture (up to 100 total coliform per one litter).

II Category - waters suitable for swimming and recreation (up to 5000 total coliform/l).

III Category - waters of ports (more then 20,000 total coliform/l).

This project's protocol for the sustainable ecotourism development tried to address both natural resources limitation and socio-cultural constraints. The general ecotourism protocol is presented in the Table 5. Due to lack of spatially explicit data for required parameters that describe environmentally suitable beach areas, it was necessary to modify ecotourism protocol so it can be applied in this project (Table 6).

1. Environmental conditions

Natural Resources:

- geomorphological (slope) and physical characteristics of the coastal area (currents, tides, bathymetry bottom substrate) (Table 5 and 6)
- physical, biological, chemical characteristics of marine ecosystems: temperature, salinity, transparency, marine species, pathogens, fecal coliforms (Keckes, 1972, Kator, 1993)

Human Resources:

- existing use of the area

- anthropological impacts (sewage system)
- water supply (Table 8)
- energy supply
- food supply (agriculture, fisheries, aquaculture)
- sustainable infrastructure design
- cultural heritage preservation

2. Physical accessibility

- roads and access to beaches
- communication dependence on land and by waterways

3. Other conditions

- other existing or potential "uses" of the same area such as nature reserves, marine sanctuary, protected species, SAV, migratory pathways, etc.

<u>Use Interactions/Conflicts:</u>

(Tables 7 and 9)

1. Beach area (Ecotourism) - Environment

Potential effects of ecotourism consider modification of water quality in the beach areas, even though environment has to have required conditions for suitable beach areas. Also potential effects consider water supply, energy supply, and food supply.

2. Beach area - Mining

The use interaction considers spatial conflict and mining can cause modification of water quality.

3. Beach area - Port (Marina)

The use conflict is spatial they can not physically coexist in the same place.

4. Beach area - Reserve sites

There is a spatial use conflict between two uses.

5. Beach area - Sewage system

The spatial use conflict exists.

6. Beach area - Hunting

There is a spatial use conflict between those two activities.

RESULTS

Natural Characteristics of the Croatian Coast

The Adriatic Sea is an elongated basin (139,000 km^2) of the northern Mediterranean, extending for 800 km into the European continent (Fig. 2). On its southern side the Adriatic Sea is connected with the Mediterranean Sea through the narrow (70 km) Otranto Strait with a sill depth of about 800 meters. The renewal of the Adriatic water is estimated to be 5 to 10 years, which is about ten time shorter than the whole Mediterranean water renewal (70 -100 years) (Ovchinnikov, 1983).

The volume of the Adriatic basin is 3.5×10^4 km^3. It presently receives one third of the total freshwater input to the Mediterranean basin. Sixty percent of the total freshwater input to the Adriatic (3000 m^3/s) enters from north, and 60% of this total is derived from the river Po (Cavazzoni Galaverni, 1972).

The entire Adriatic receives an average of 142 km^3/y of freshwater of which 45 km^3/y comes from the Istrian and Central Dalmatian drainage basin, mainly karst underground streams; an estimated 2.2 km^3/y enters Rijeka Bay (Degobbis, 1981). Freshwater discharges generate temperature and salinity gradients between the western and eastern north Adriatic coast and between north and south parts of the Island Cres Archipelago (Franco, 1970; Bicanic, 1989; Stirn, 1969).

The length of the Croatian coastline is 1778-km mainland, plus 4012 km of islands coastline, totaling 5790 km. Due to the great number of islands (1185) with total area of 3,100 km^2, the Croatian coast of the Adriatic Sea is often referred to as the "coast with a thousand islands". There are 66 inhabited islands and islets, 652 uninhabited islands and islets, 389 rocks and 78 reefs. Among the islands are nine having more than 100 km of coastline, six medium size islands with 50-100 km of coastline, 45 small islands having 10-50 km of coastline, and six having less than 10 km of coastline.

Because of the indented coastline, the Croatian littoral is considered to be one of the most indented coasts in the world, along with the Aegean, Norwegian, or South Chilean coasts. The world's geographic literature recognizes the term "Dalmatian coast type" (Heinrichsen, 1998), which denotes a type of coast having plenty of parallel coastal and island forms. The term originated from the Croatian littoral - Northern Dalmatia.

Natural Characteristics and Resources of the Island Cres

(The Resource Assessment)

The Island Cres is part of the Cres-Losinj archipelago, the largest island group in the Adriatic Sea. It displays a variety of the features typical of Mediterranean limestone and sandy islands. The 45th parallel latitude north passes across the Island Cres (Fig. 3).

The great variety of landscapes, vegetation and soils, and environmental conditions together with an extremely attractive coastline with numerous springs that rise to the sea surface, makes this island representative of both typical and specific landscapes found on other Adriatic islands (Table 1). Island vegetation reflects the great landscape variety, from the bare karst terrain and macchia (dense evergreen underbrush), to the Mediterranean pine woods and complexes of forest (oak, hornbean) preserved mainly at the northern part of the island. Tourism, shipping, agriculture (olives, vine) and fishing are the most important economic activities.

Lithosphere and Geology

Tectonically, the Island belongs to the Adriatic structural unit of the Dinarides (Herak, 1986) with overthrust structures comprising the main feature. Tectonic movements took place during the early Tertiary that resulted in the shifting and rotation of a wide structural complex, accompanied with constant changes in the direction of regional stress. During the recent phase of neo-tectonic activity longitudinal faults moved tectonics blocks and formed the Lake Vrana depression, a fresh water source below sea level (Anderson and Jackson, 1987).

The Island is mainly composed of karst carbonate rocks, the dominant rock type within the archipelago (Fig. 4). There are predominately Cretaceous limestone/dolomite strata, and the Cretaceous and Paleogenic formations are part of the northern Adriatic Dinaridic base structures that have northwest-southeast axis. There are Eolian and Quaternary sandy sediments to the southwest which are semi-cemented sand blown from the Po river delta (Cati, 1981).

Terra rossa reddish-brown sandy clay containing carbonate debris forms the youngest Quaternary deposits and fills depressions of karst relief in absence of surface streams. Although very thin, these deposits are sufficient to support vegetation. Larger accumulations of terra rossa are associated with dolomitic zones that are less resistant to weathering than limestone (Urbanisticki Plan, 1991). The Island's arable soil is insufficient for intensive cultivation. Consequently, agricultural practice tends towards olive-trees and livestock breeding (Fig. 5). Extensive, grass-covered areas on the dolomites are suitable for sheep grazing, which has always been a traditional activity in the economy of the island (Fig. 6).

Current sea levels are approximately 100 m higher than during the last glacial period when the entire northern Adriatic Sea was the delta of the river Po (UNEP, 1994). There were occasional desert conditions during which thick deposits of sand accumulated on the mountains at the delta edge.

Marine Ecosystems

The Northern Adriatic is 135 km wide with an approximate depth of 33.5 meters. The influence of the freshwater along the north coast of the Bay is highly variable with surface salinities varying between 23.0 and 37.8 ‰ (Degobbis, 1983) (Table 1).

The structure of the water column in the Island Cres area is characterized by several layers and pycnoclines (Degobbis, 1981). Waters of lower transparency are generally green and less frequently brown depending on the phytoplankton species (Precali and Smodlaka, 1983) (Table 1).

Water exchange and dynamics

The marine environment surrounding the Island Cres and associated archipelago is under the strong influence of meteorological, oceanographic, and hydrographic conditions of the north and central Adriatic Sea. The average tidal variation is approximately 80 cm, reaching 200 cm in exceptional circumstances (Stravisi, 1991). Sea-level changes are caused by various meteorological perturbations, particularly by winds and fluctuations in air pressure (meteorological tides). These changes are less predictable, and their duration can vary from hours to several days. An air pressure change of 1 hPa induces 1cm of sea-level change. Winds of 10m/sec, "bura" and "sirocco" (jugo) generate sea level changes up to 10 cm. Southern winds generate seiche, whose basic periodicity in the open sea is 22 or 11-12 hours, with amplitude of 50 cm (Buljan and Zore-Armanda, 1976). Atmospheric pressure differences between the North Atlantic and eastern Mediterranean significantly influence the intensity of the current in the northwest direction and the exchange of water between the Adriatic and Ionian Sea.

The currents have a generally circular pattern, with a northwest current reaching the eastern coasts of the island changing direction in the North Adriatic and continuing (after mixing with freshwater from the river Po) along the western Adriatic coast towards the northeast (Purga et al. 1979). In the North Adriatic region during the spring, eddy circulations are established due to increased freshwater inputs (Franco et al. 1982; Cerovecki et al. 1991). Cyclonic eddies are formed in the northern part of the region, which in combination with northern Adriatic water contribute in formation of the surface layer in the western parts of the Island (Degobbis, 1983). Due to this circulation pattern, surface waters with reduced salinity are redistributed during the summer over this region (Gilmartin et al, 1990). In the winter the cyclonic circulation can accelerate by "bora" and reach velocities up to 1 m/sec.

Water Quality

Dissolved oxygen

Oxygen saturation in the north Adriatic Sea range from zero in bottom waters to as high as 270% in the surface layers (Smodlaka and Degobbis, 1987) (Table 1). Significant super-saturation occurs during late winter and spring, and in autumn when phytoplankton concentrations are high (Gilmartin et al. 1990). Oxygen depletion of bottom water below the pycnocline occurs in mid-autumn when oxygen consumption due to decomposition of organic matter exceeds photosynthetic production. During late autumn and winter biological activity is minimal, and effective vertical mixing leads to oxygen redistribution throughout the entire water column, 90-100% saturation (Zore-Armanda et al, 1991).

Nutrients

Nutrient concentrations are significantly lower in the Adriatic than in the Atlantic (Cescon and Scarazzato, 1979). The northern part of the Adriatic Sea is one of the most productive area of the Mediterranean region due to nutrient inputs (anthropogenic) from rivers and streams, particularly the Po River (1500 m^3/s) (Cati, 1981).

Annual primary production ranges from 55 $gC/m^2/y$ in the open sea to 150 $gC/m^2/y$ in the river plumes and polluted harbors (Homen, 1979; Pucher-Petkovic et al. 1988). In the western part of the open north Adriatic the primary production is significantly higher (100 - 120 $gC/m^2/y$) than in the eastern part (55 - 80 $gC/m^2/y$) (Gilmartin and Relevante, 1983). In the open waters of the north Adriatic, chlorophyll *a* concentrations vary from 0.0 to 100 g/l, with maximum of 250 g/l in the Po River plume (Socal et al., 1982; Smodlaka, 1986).

Significant changes in nutrient concentrations were recorded in the North Adriatic Sea along salinity gradients and in the deoxygenated bottom layer (Franco, 1984). In the Cres area the total inorganic nitrogen and orthosilicate are twice as high as in the open central Adriatic sea, due to freshwater inputs (Degobbis, 1983). Peaks in flow and nutrient input from the river

Po occur in spring and autumn.

Eutrophication induced by excessive inputs of nitrogen and phosphorus from point and nonpoint sources is a significant problem in the North Adriatic (Filipcic, 1990). Nutrient stress causes harmful algal blooms (HAB), red tides and formation of mucilaginous macroagregates over a large area of the North Adriatic during late spring, summer and early autumn (Malone et al. 1996). First observed in 1729, and more frequently in recent decades, these mucilaginous macroagregates result in high mortality rates of benthic flora and fauna. The underlying causes are not well understood.

Coastal biota of the Island

The marine flora and fauna around the Island are mainly comprised of Atlantic-Mediterranean and endemic Mediterranean taxa. The supralittoral benthic community of rocky shores is widely distributed and most developed at exposed sites. The biota of upper sublittoral zone on rocky substrates is dominated by algae, which are, at some sites, suppressed by sea urchins. Sandy sediments in sublittoral zone support local seagrass beds of *Cymodocea* and *Zostera* (Fig. 7).

Eelgrass (*Posidonia oceanica*) communities are locally dominant on the coarse sand and gravel sediments of the upper sublittoral zone (these are protected habitats) (Fig. 8). The wide coastal zone around the Island is dominated by a community characteristic of sublittoral bare coarse sands, fine gravels, and detrital bottom substrates (Fig. 9). Norway lobsters (*Nephrops norvegicus*) characterize the lower sublittoral silty sediment in the eastern part of the Island and soft bottom community of the Kvarner Bay. Economically, the most important pelagic fish is the sardine (*Sardina pichardus*) (Fig. 10).

Coastal geology of the Island

The coastal zone is mainly rocky Mesozoic limestone with some Holocene sand deposits. Along the gentle submarine slopes coarse-grained or fine-grained sand deposits cover a compact rocky base. In the calm areas they are covered by silt. The coastline is shallowly indented and consists of vertically inclined rocks falling vertically into the sea. There are widespread minor cracks caused by tectonics or erosion, creating a few submarine caves. Most beaches are gravel although a few are sandy (Fig. 9).

Sediments covering the seabed are composed of carbonates and silicates (Degobbis, 1990). The carbonates, formed in the late Pleistocene, originate from the outer Dinarides that are stretching along northeast part of the Adriatic Sea and are mostly biogenic. The silicates, found in the southwest, also bear biogenic detritus and were transported and sedimented by the paleo Po (Cati, 1981).

Island hydrogeology

Overthrusting of carbonate masses and considerably lower sea levels during the geological past resulted in suitable natural conditions for the formation of deep karst aquifers within Dinaric section of the Adriatic Sea and within Cres (Herak, 1986). Although predominantly composed of karst, these rocks have significantly different hydrogeological properties due to differences in lithology, degree of deformation, and position within structural formations (Fig. 11).

On the Island there are three groups of rocks:

1. Highly permeable karst carbonate rocks of different ages or a complex of rocks in which limestones prevail. The porosity of this rock group is high.
2. Low permeable carbonate rocks (dolomites) whose degree of permeability increases with increasing limestones content within the dolomitic complex.

3. Impermeable clastic rocks, such as flysch deposits within which marl predominates, forming a whole complex of impermeable deposits.

There are no permanent streams on the island, although there are several short ephemeral streams that drain toward the sea and toward the lake Vrana (UNEP, 1994). Evaporation, evapotransporation, and effective infiltration into the ground water (Table 8) primarily affect the water budget of the island.

The amount of precipitation that enters the karst formation, as estimated on data from neighboring, continental drainage areas is about 40%. The insular runoff from karst drainage areas is associated with numerous small coastal springs, submarine springs (vrulja), and with Lake Vrana. Numerous coastal and submarine springs are found along the coastal areas of the Island. During dry summer months they dry up or diminish to the point that they do not influence the water budget.

Lake Vrana

The Lake Vrana, situated in the center of the Island Cres, is an important hydrogeological feature (Table 1). It is a cryptodepression whose depth is 74.5 m, with an average water level of 13 m above sea level. The lake's local drainage area is approximately 33 km^2, and the hydrological regime is balanced with the average annual precipitation of 976 mm and evaporation of 1520 mm/year (UNEP, 1994).

This lake is not typical of the Dinaric karst. The lake depression is of tectonic origin, formed along the so-called Vrana fault that was activated by neo-tectonic movements (UNEP, 1994). The impermeable flysch and low permeable dolomites, barriers to water movement, penetrate deep underground of the island suggesting possible hydraulic connections between the lake and its local drainage area, and also between the lake and continental mainland (Biondic et al. 1992).

There is no visible flow of ground water into the lake. An attempt to trace the ground water flow from the hinterland was unsuccessful. The results of a recent research project in collaboration with the Institute of Nuclear Research from Debrecin, Hungary (European COST project) confirmed the present hypothesis that the lake recharge occurs not only via its local drainage area but also from distant areas. This inflow of water occurs in the deepest part of the lake, 68 m below the sea level.

Lake Vrana may be defined as a karst field formed when the sea level was 100 m lower than present, which has been recently inundated by ground water. Generally, the lake stages are controlled by the water level fluctuations in deep karst underground. This lake is the only public water-supply source for this group of islands (UNEP, 1994). Existing water budget analyses show that the present rate of pumping approaches the upper limit and any increase in the amounts extracted will lead to depletion of this water resource (Table 8).

Terrestrial Ecosystems

In the past Cres was entirely covered with forest vegetation, represented by two climatic vegetation types. Deciduous sub-Mediterranean forests *Querco-Carpinetum orientalis* community covered the northern parts of the island and areas above 250 meters altitude and the southern parts of the Island and lower altitudes were covered by an evergreen oak, *Orno-Quercetum ilicis* community (Fig. 12).

Today, forest covers 60% of the island area, with the remaining 40% in pastures and agricultural land (Fig. 6). Although the development of cattle farming brought increased degradation of the natural forest cover, depopulation of the island has resulted in the neglect of some agricultural areas that are now being overgrown with forest vegetation.

Due to its location in the northern part of Adriatic and influence from Mediterranean zone, mixed faunal elements of eastern and western Mediterranean region occur here on the Island. Of all Adriatic islands, Cres is the only one where the mole (*Talpa europea*) and field mouse

(*Apodemus flavicollis*) occur. The herpetofauna is represented by 12 species of lizards. It is the only island with the common wall lizard (*Poderas muralis*). Amphibians in the lake Vrana are represented with 7 species, among them the agile frog (*Rana dalmatina*), the yellow-bellied toad (*Bombina variegata*), and the smooth newt (*Triturus vulgaris meridionalis*). The ornithofauna is very rich (162 species), with one endangered and protected species, the griffon vulture (*Gips fulvus*) (Fig. 8). The largest predator is the beech marten (*Martes foina*); the black rat (*Rattus*) was introduced to the island.

Human resources (Infrastructure)

Settlements, roads, quarry, and port-marina are shown in Figure 16. Bauxite deposits in western and eastern parts of the island have been discovered by erosion. Deposits are small size (10,000 tons), and are often covered by foraminiferal Eocene limestone (UNEP, 1994). Construction stone consists of foraminiferal limestone from the lower to middle Eocene.

Tourism (ecotourism) is currently a main industry on the island and represents important economic support (UNEP, 1996a). Table 8 shows distribution of population by settlement and current tourism accommodation.

Aquaculture

(Suitability and Impact Assessment)

The coastline of Cres is 280.4 km long as digitized for this project from the bathymetric map (1986). The open coast measuring (digitizing) estimate included the coast length of embayments. The GIS shoreline process estimated the island's shoreline length to 243.1 km (Landsat TM band 4, Acquisition Date: March 1985). The literature refers to the average indented coastline index of about 1.60, and a coastline length of 250 km (Plan, 1990).

Most of the rocky shores are rather steep and face the open sea, exposer to strong and gusty winds makes them unsuitable for the installation of mariculture facilities. Along the coast there are only few calm bays, most of which are traditionally occupied with urban, shipyard and harbor settlements.

In the beginning of the century when shellfish culture was introduced in this area, the best location for the production of oysters was found in the very calm and shallow inner part of the Bay of Cres. Here modest fresh water springs supported favorable conditions for oyster cultivation. In 1910 the capacity of oyster production was ~ 100,000 oysters per year. Other calm and flat bays were traditionally used as protected fishponds, where fishermen used to hold adult fish for the market or collect juvenile fish for fish farming. Near the urban centers of Cres, shipyards and harbor activities started to expand, with a high intensity of tourism which has become one of the most promising economic activities in the region. Most of the remaining bays are now excluded as potential locations for aquaculture.

At present there is no aquaculture in this region, but part of Bay of Valun and the Bay of Ustrinska have been considered for such developments (Fig. 25). The most suitable area the Bay of Cres has been definitely excluded from any future mariculture development due to existing port and marina in the inner part of the bay.

Spatial analysis for aquaculture based on natural resources

(Figs. 20, 21, 22, 23)

Based on literature review a generic aquaculture protocol was created for the purpose of this project (Table 3). For the purpose of the spatial analysis and implementation of the aquaculture protocol on the Island, a modified version of the aquaculture protocol was created based upon spatially explicit data availability (Table 4).

1. A buffer zone was created 200 and 300 meters off the island's shoreline, and another buffer zone was created 100 and 200 meters inland (selection of the buffers is related to slope functions).

2. With the *Arc* command UNION several coverages were combined: buffered shoreline, bathimetry polygon coverage, and topography polygon coverage, creating a coverage *aqua300* (Table 2).

3. The *Arcplot* command next step reselected from the coverage *aqua300* the physically suitable aquaculture areas from offshore buffer zone areas that were equal or deeper than 30 meters and outside the 200-meter zone. This logical expression was based on the criteria from the protocol for aquaculture (Table 4), regarding bathimetry, sheltered area (considering NE wind effects in bays), circulation pattern, and slope (Fig. 20).

4. The next logical expression involved reselecting inland areas that are up to 50 meters altitude and outside of the 100 meters buffer zone. This logical expression selected areas with lower slope, providing reduced erosion potential and easier access (Fig. 20).

5. The next parameter evaluated was the type of benthic substrate. Sandy bottom polygons were selected from the same offshore buffer zone (Fig. 21).

6. Existing salinity data were not adequate for this project. They were not spatially explicit and could not be used for spatial analysis. A proxy, presence or absence of submarine springs was used as an indicator for suitable salinity for aquaculture. (Submarine springs decrease salinity, favoring aquaculture activity.) (Fig. 21)

7. Submerged aquatic vegetation (SAV with 200m buffer zone) areas were selected as unsuitable sites for aquaculture activities, because of the high natural resource value of SAV beds (Fig. 21).

Spatial analysis for aquaculture based on human resources

(Fig. 24, 25, 26, 27)

8. A 0.5-km buffer zone in the coverage roads and settlements was created and combined with *aqua300* coverage.

9. Areas from the unionized coverage (*aquabest*) that are physically suitable for aquaculture and within 0.5 km buffer zone were reselected as accessible and suitable for aquaculture.

10. The next step included reselection of the unsuitable water quality polygons (the only available and useful data for water quality considered port and marina in Cres Bay).

Analysis Recommendations:

- Other steps would include adequate measurements of water quality, salinity, temperature (surface and within water column) during each season, water circulation patterns and stratification.
- Adequate measurements and monitoring should include trophic conditions, clarity, and desolved oxygen.
- Measurements of the potential erosion sites along the shoreline of the Island.

Results of the spatial analysis are shown in Figure 32 and Table 9, and the results of the spatial use conflicts are shown in Figure 33 and Table 7.

Ecotourism

(Suitability and Impact Assessment)

Spatial analysis for potential beach areas based on physical suitability

(Figs. 28, 29)

1. Buffer zones of 100 and 200 meters were created offshore and inland (Fig. 28). Selection of the buffers is related to the required slopes (protocol for ecotourism).

2. The union of several coverages (*beachbuf* with bathymetry polygon coverage, and topography polygon coverage) created *beach200* coverage for reselecting potential beach areas based on the physical suitability.

3. The logical expression: reselect 5 meters bathymetry areas outside 100 meters buffer zone, reselect 50 meters altitude outside 100 meter buffer zone. With this expression relatively shallow-extended beach areas were selected with lower slopes as adequate for potential beaches (Fig. 29).

Spatial analysis for potential beach areas based on human resources

(Figs. 30, 31)

4. A buffer zone of 2000 meters was created around roads, as a beach access indicator. Reselecting provided accessible beach areas within the 2-km buffer zone (Fig. 30).

5. From the infrastructure coverage, the port area with degraded water quality was selected as an unsuitable recreational site (Fig. 31).

6. Spatial analysis for tourism development was based on available attributes: water demand/supply, tourism carrying capacity regarding beach area and water quality (fecal

coliforms), number (#) of available tourist beds, and number of residents (Table 8).

Analysis Recommendations:

A next step would be adequate monitoring for water quality (E.colli, pathogens, heavy metals, etc.), wastewater treatment technology, potential nutrient input from swimmers, and incorporating all this information into spatial data layers.

Results of the spatial analysis for potential ecotourism development

Carrying Capacity for Ecotourism should be based on available beach area/person, water supply/person, energy supply/person, sewage system/person, and food supply/person (Table 8).

1. Calculated potential beach areas based on the physical parameters:

From selected suitable polygons the shoreline for potential beaches was calculated to be 67,315 meters, with an average width of 10 meters. The estimated potential beach area on the island is:

$$\mathbf{67{,}315\ meters \times 10\ meters = 673{,}150\ m^2}$$

It was assumed that standard for beach area per person is 10 m^2/person (PAP, 1994), then this area can support approximately 67,000 people.

2. Calculated potential beach areas based on the beach accessibility:

$$\mathbf{44{,}400\ meters \times 10\ meters = 444{,}000\ m^2}$$

Based on the same assumption this area can support approximately 44,400 people.

3. Potential beach carrying capacity:

$$\textit{Beach } m^2 / 10\ m^2 = \#\ \textit{users}$$

Considering the island's beach capacity: 44,400 m x 10 m = 444,000 m^2 of potential beach area. If the standard for beach carrying capacity is $10m^2$/person, than the island can support 44,400 people.

4. Water supply/demand issue:

Water standards liters per capita per day (UNEP, 1994):
Residential = 200
Hotels = 400
Nautical = 150

The existing water supply system consists of the pumping station of total capacity 262.5 l/s, with maximum pumping rate of 150 l/s. The current demand is approximately 70 l/s, reaching 150 l/s during the summer season (UNEP, 1994).

For the purpose of this project the water demand for a person per day (Table 8):
250 liters = 0.003 l/s/person
3,238 residents use ~ 9.7 l/s
+17,085 tourists use ~ 51.3 l/s
20, 323 people use ~ **61.00 l/s**

Considering maximum pumping rate of 150 l/s with existing total pumping capacity of 262.5 l/s (the lake Vrana capacity). the island's water supply could support approximately 50,000 people. If water demand would be considered as 400 l/day/person the island would be able to support only 30,000 people!

5. Water quality issue:

The Cres Bay (Piskel) with a port and marina has unsuitable water quality for recreational activities therefore this area of 35,800m^2 is unsuitable beach area. As a result of the spatial use conflict analysis the potential beach area is estimated on 408,200m^2 and can support approximately 40,820 people (Table 8). Spatial use conflict analysis for ecotourism development is shown in Figure 34 and Table 7 and 9.

DISCUSSION

Planning for sustainable development of a given area, in this case the Island, requires careful consideration of the multiplicity of factors and their interactions that often leads to contrasting needs. An adequate land-use policy includes the resolution of conflicts, but this process is often hindered by the lack of information and appropriate methodologies. The technique of multiple criteria analysis helps to overcome methodological problems and permits manipulation of heterogeneous information (Niu et al. 1993). Planning is a process that comprehensively analyzes coastal systems (natural resources, uses, and anthropologically impacted environment) in order to produce a framework to guide decision-makers in possible allocations of scarce resources among competing interests.

The first step in developing a CZM plan is to create and integrate simple information systems that can provide appropriate inputs of space specific information for decision-making. In general, information about coastal zone is of two types: space-dependent and space-independent information (Weyl, 1982).

- Space-independent information encompasses information about materials, biological organisms and physical, chemical, geological, biological, social, legal, and political processes.
- Space-dependent information relates to the particular topographic, geographic, climatic, ecological, and socioeconomic characteristics of the coastline to be managed.

Sustainable development has an explicit spatial dimension; therefore it is necessary to develop a spatial framework for environmental accounting, which will distinguish the spatial and temporal dimensions of sustainability. Such a consistent and conceptual framework will foster the development of appropriate methodologies for the comparative evaluation of sustainable development on local, national scales as well as on regional and global ones.

The scale issue is a very important factor in developing a spatial framework. A broad scale database may give an appropriate description of a region but is not useful for specific in situ problems. This issue has to be addresses in developments of environmental assessments and monitoring programs. It is essential to establish a protocol that will be able to guide inventory and data collection effort, in order to improve environmental monitoring programs and prioritize research needs.

Dynamic modeling within a simulation framework is be based on the impact assessment, which includes the analysis of both biological and physical environmental factors. Model building is an essential, prerequisite for comprehension and for choosing among alternative actions (Constanza and Matthias, 1998). Digital elevation model (DEM) is an elevation in digital form representing the continuous variation of relief over space (Burrough, 1986). Matching the environmental requirements for the activity (aquaculture and ecotourism) generated the framework used here with environmental characteristics of the area (the island). One of the most important factors in creating suitability maps was the availability of spatially explicit data.

Remote sensing information can be assimilated into GIS and integrated with ArcInfo database to elucidate the linkages, interactions and constraints between human activities and environmental resources in order to allow effective management. Remote sensing and GIS can be technically linked in models that incorporate spatial and process analysis capabilities, creating Integrated GIS (IGIS). By linking technologies, concepts and theories of both the information system becomes richer and more sophisticated and useful in substantive applications (Davis and Simonett, 1991). This approach will ensure the restoration, and protection of the long-term sustainable productivity, both ecological and economic of the coastal zone. The protocol I developed highly recommends application of the IGIS in ICM planning processes.

Spatial use conflicts refer to the existing or potential use of a land/water unit by incompatible activities. The framework developed here provides a basis for assisting both the location and quality of the conflicts. When there is a spatial use conflict, such as between aquaculture and beach areas, the policy decision must also include economical and social considerations. The approach should explicitly be based on the assumption that environment sets the limits for sustainable development. Economic and social considerations form the next step in the process of decision making.

Management choices will be required when certain activities can appear in the same locations based on suitability analysis of the area. In these instances, choice has to be based on environmental requirements for the activity and their interaction with the environmental resources (impact assessment). First priority should be given to the activity that has the highest environmental suitability level and the lowest adverse impact on the respective land/water system. Implementation and final decision making must incorporate socio-economical suitability, cultural, and political factors.

Each government has the responsibility to determine the appropriate balance of the resource preservation and utilization on any given area. This decision should be based on influences of the various sectors of the local community on the planning and management processes. Involving the community in the planning and decision-making process is an important step toward acceptability and success of the management project.

The management program should include planning, applied research, environmental monitoring, and education (public outreach). It is difficult to measure sustainable development. Monitoring has to be based upon identified and measurable parameters clearly related to management goals. Countries should develop systems for monitoring and evaluating progress towards achieving sustainable development by adopting indicators that measure changes across environmental, economic, and social dimensions (UN, 1994).

The International Organization for Standardization (ISO), a non-governmental organization, and a global consortium of 90 nations was established to promote international standards affecting trade of goods and services (Lathrop and Centner, 1998). ISO 9000 series of standards for quality management provided a process by which a firm may be certified as complying with relevant management and quality auditing criteria, across international boundaries. There are limited environmental components to the ISO 9000 standards. Therefore, in 1991, ISO set up the Technical Committee for Environmental Management Standards (ISO 14000) to provide organizations worldwide with a common approach to environmental management. The ISO 14000 standards are process, not performance, standards and are still being developed and designed to evaluate and certify environmental management practices, environmental auditing, environmental performance evaluations, environmental labeling, life-cycle assessments, and environmental aspects in product standards (Tibor and Feldman, 1997). By studying the certification standards of ISO 14000, countries will be able to secure guidance for information and reporting standards that developers should be expected to apply for different types of activities in coastal areas. Information should become available and useful to the stakeholders in private and public sectors, as well as to the general public.

Public education (outreach) including "marketing" of policy should use environmental information and explain the use of BMPs to help foster long-term sustainable development projects. Marketing based on environmental quality competition (Blue Flag, Ecostar) provides certification for the environmental quality in the coastal areas.

Any region's economy should avoid a heavy reliance on one sector and practice multiple-use strategy that is less susceptible to unanticipated fluctuations in price. No single sector of the economy should be given an absolute control over an area and in the same time try to manage activities in an environmentally responsible way.

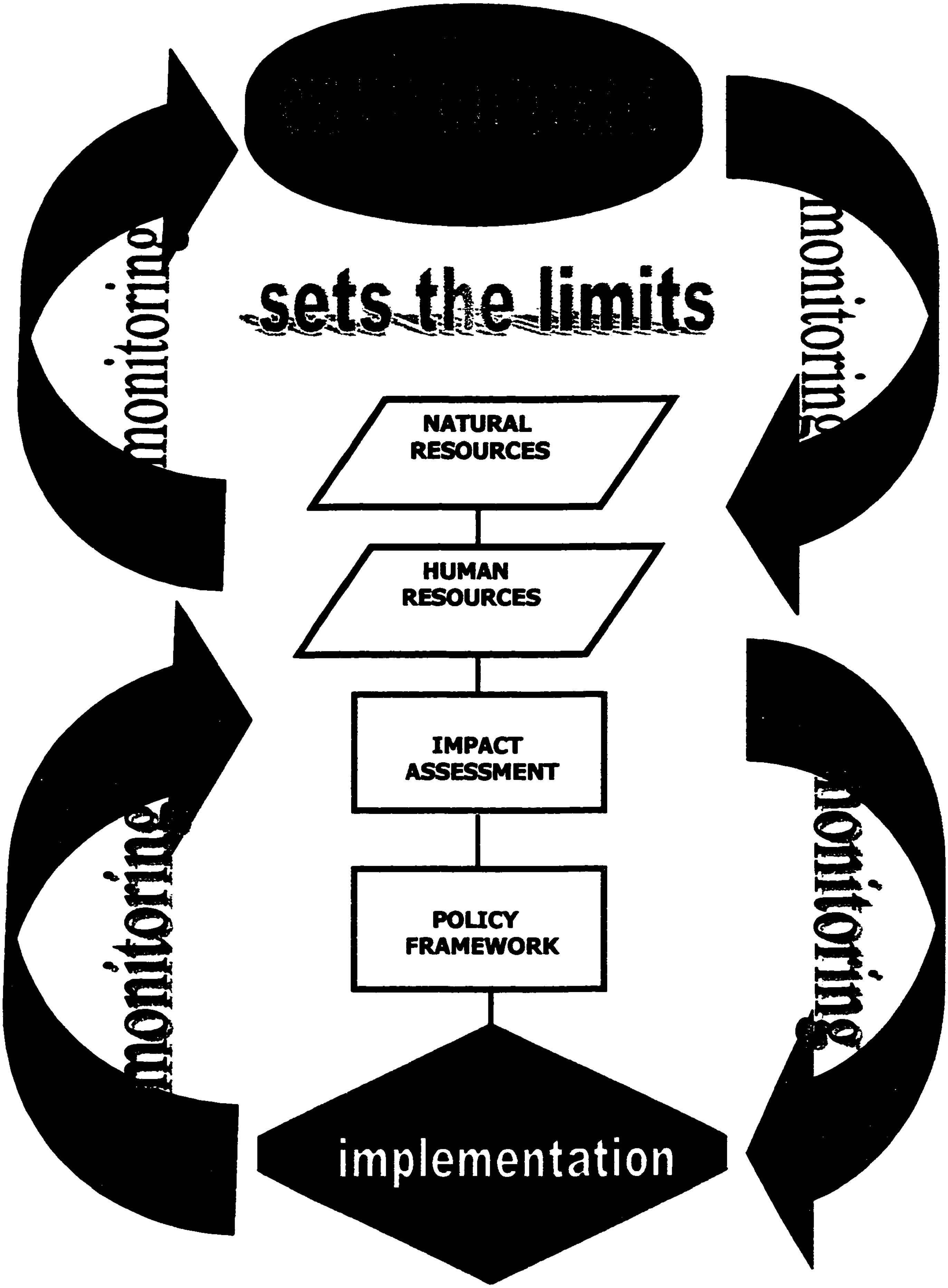
The framework for ICZM decision making developed and tested in the Island Cres scenario is one that can be used in many other areas with potential for a range of development options.

This framework incorporates interdisciplinary aspects of the ICZM, and establishes protocols based on scientific disciplines that are often used broadly by coastal managers in decision making process. The protocol approach makes sure that people with less knowledge about specific physical, chemical, biological activities in the coastal ecosystems, can understand the importance of them, and use it on different scale levels.

Based on assumption that environment sets the limits for sustainable development this project assessed available and spatially explicit data in order to apply protocols for aquaculture and ecotourism. Many options exist for environmental/social development within environmental limits, and successful management decisions require knowledge and understanding of "use choice" consequences. This project's strength is that it evaluates options based on the best available information but clearly indicates where better information is desirable. It establishes guidelines for best available environmental assessment, and for development of rational and integrated long-term social and economic policies for the continuing use of the Island's resources.

Through the monitoring programs (environmental and socio-economic), better information is incorporated into the main protocols, and evaluations improve closing the feedback cycle of the framework for sustainable development.

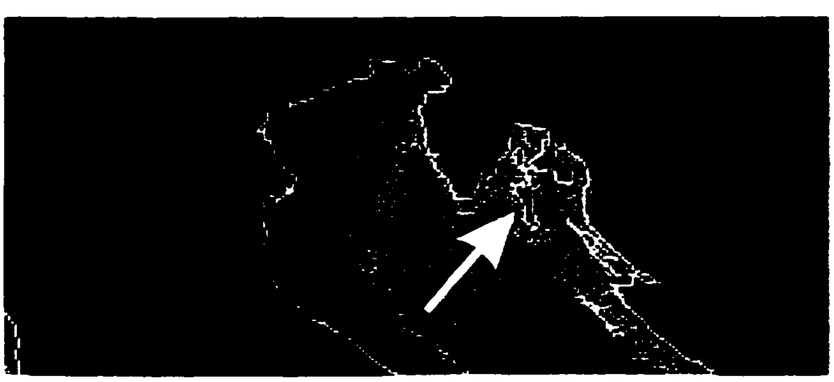
Figure 1. General Concept for Sustainable Development



GENERAL CONCEPT FOR SUSTAINABLE DEVELOPMENT

Figure 2. Mediterranean Region and Croatian Coast
Island Pilot Project Area, North Adriatic

Mediterranean Region (http://seawifs.gsfc.nasa.gov)



The Island Pilot Project Area, North Adriatic Sea, Croatia (http://seawifs.gsfc.nasa.gov)

Figure 3. Geomorphology of the Island

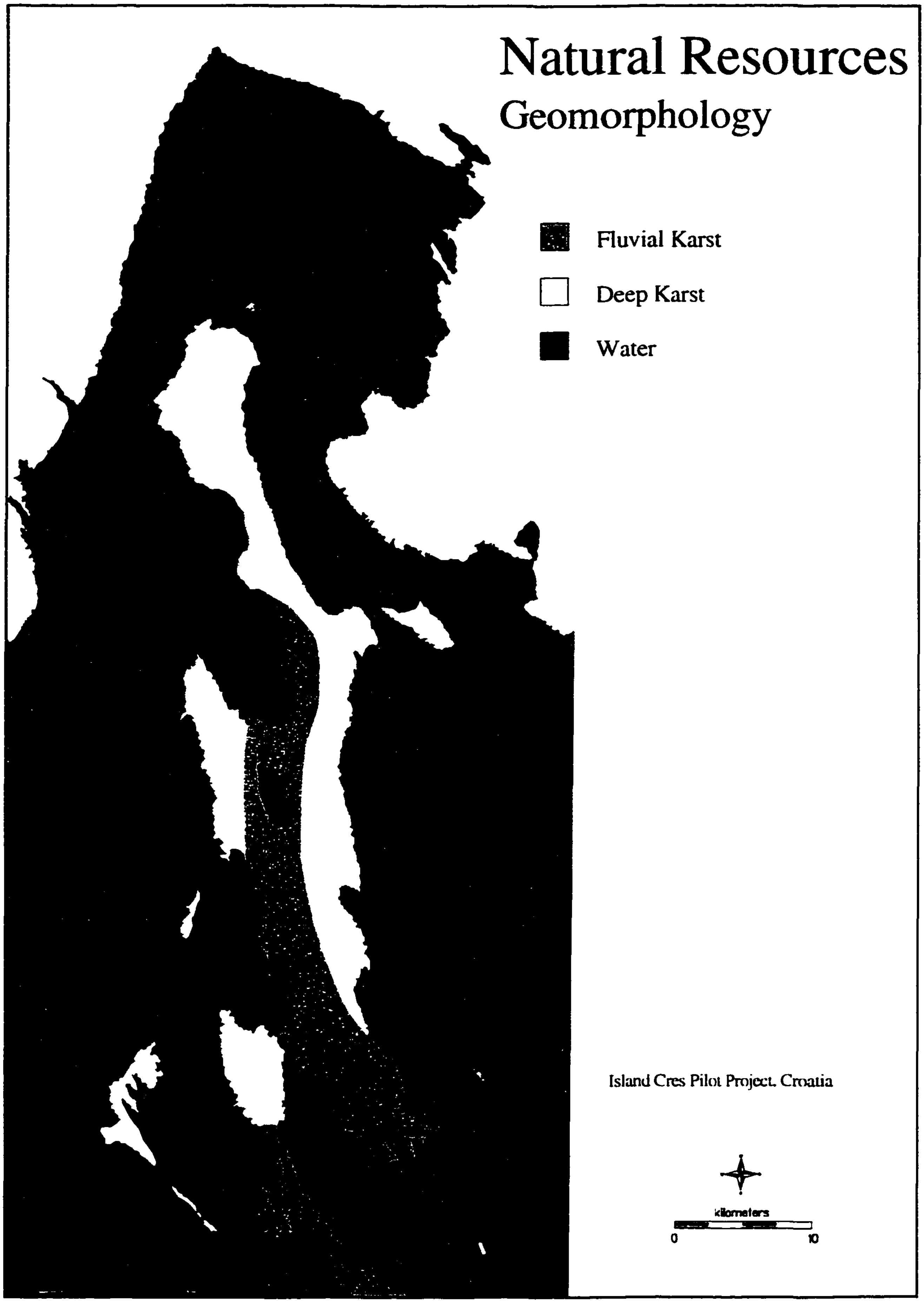

Natural Resources
Geomorphology
Fluvial Karst
Deep Karst
Water
Island Cres Pilot Project. Croatia
kilometers
0
10

Figure 4. Agricultural Areas on the Island


Human Resources
Agriculture
Suitable
Unsuitable
Settlements
Water
Island Cres Pilot Project. Croatia
kilometers
0
7

Figure 5. Island's Land use/Land cover
Landsat TM

Land use/Land cover
Island Cres Pilot Project

LANDSAT TM, May 1986

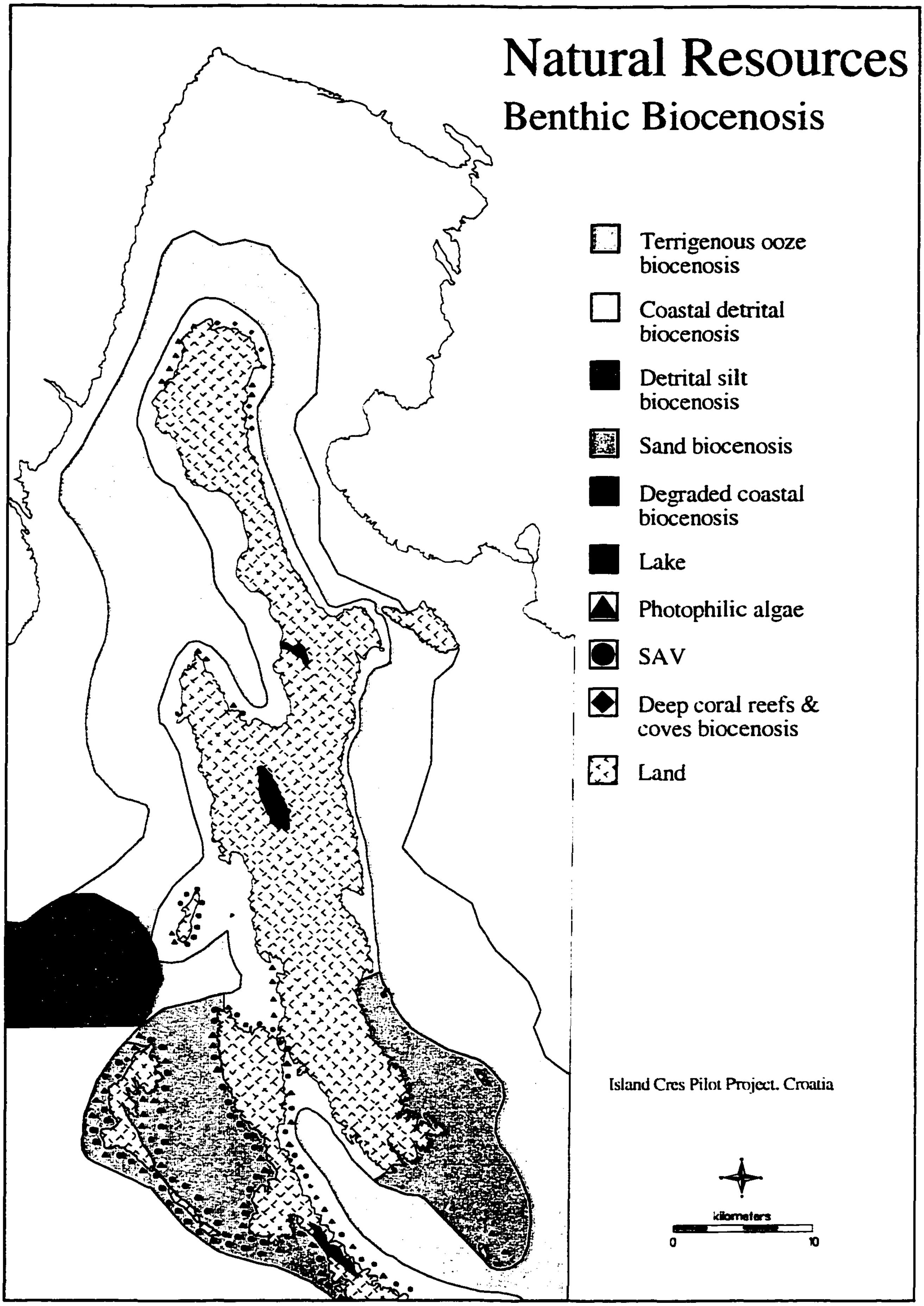
- Water (50-100m)
- Water (20-50m)
- Water (0-30m)
- Macchia
- Black pine forest
- Holly oak forest
- Downy oak forest
- Pastures & Ag
- Barren

Kilometers

5 0 5

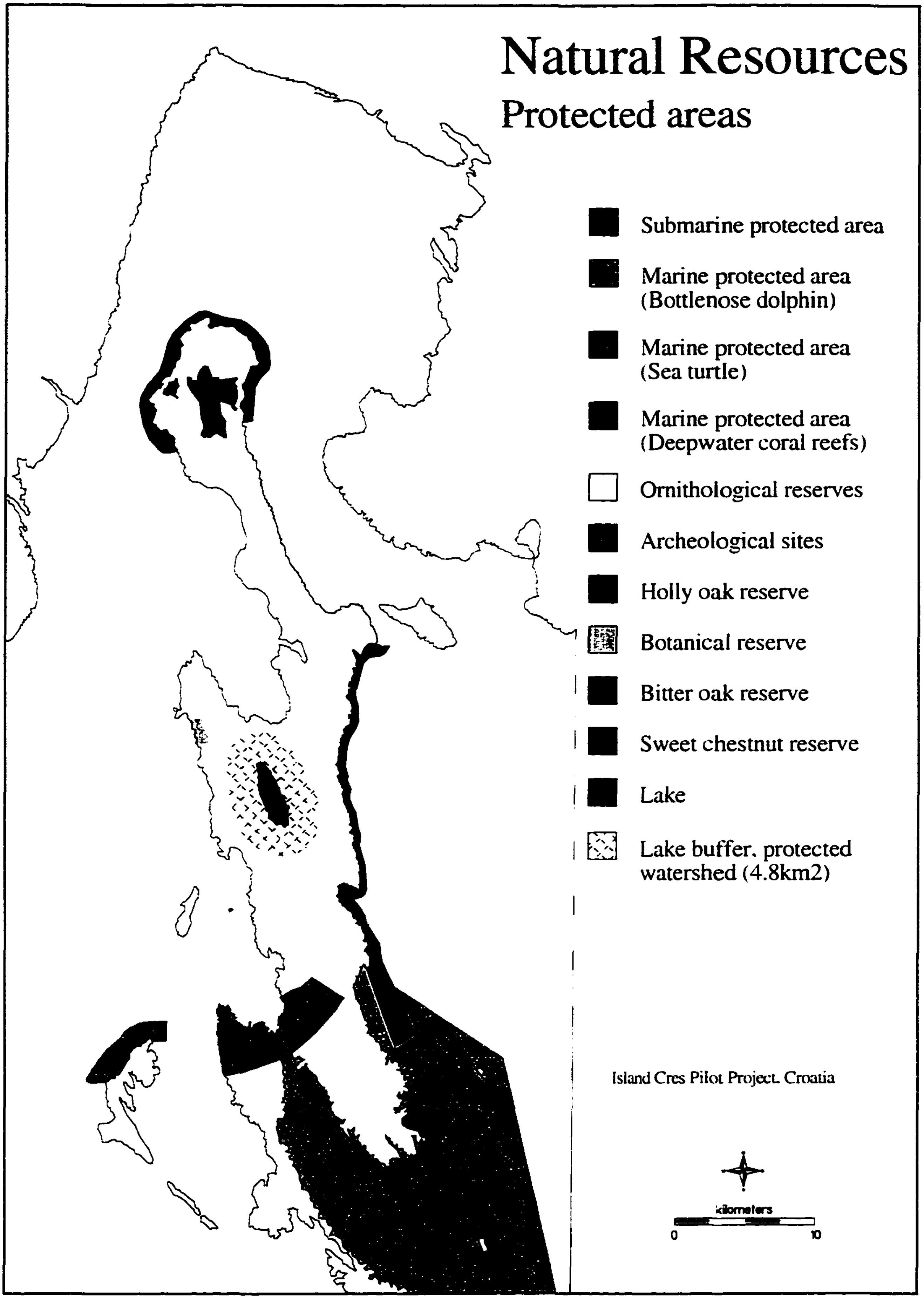
1 : 250000

Figure 6. Characteristic Benthic Biocenozis of the Island's area



Natural Resources
Benthic Biocenosis
Terrigenous ooze biocenosis
Coastal detrital biocenosis
Detrital silt biocenosis
Sand biocenosis
Degraded coastal biocenosis
Lake
Photophilic algae
SAV
Deep coral reefs & coves biocenosis
Land
Island Cres Pilot Project. Croatia
kilometers
0
10

Figure 7. Protected Terrestrial and Marine Areas



Natural Resources
Protected areas
Submarine protected area
Marine protected area (Bottlenose dolphin)
Marine protected area (Sea turtle)
Marine protected area (Deepwater coral reefs)
Ornithological reserves
Archeological sites
Holly oak reserve
Botanical reserve
Bitter oak reserve
Sweet chestnut reserve
Lake
Lake buffer, protected watershed (4.8km2)
Island Cres Pilot Project. Croatia
kilometers
0
10

Figure 8. Characteristic Marine Sediments in the Island's area

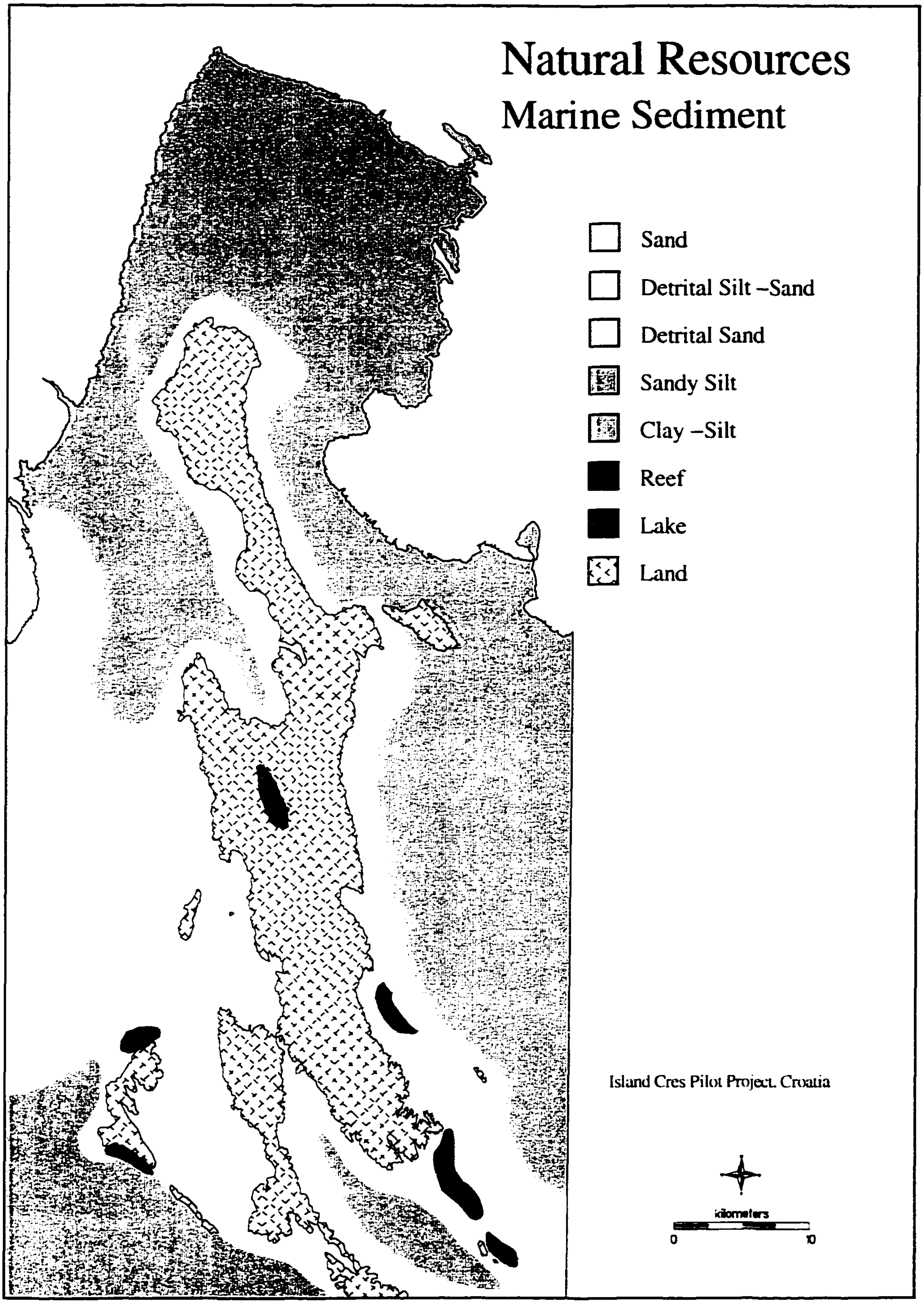

Natural Resources
Marine Sediment
Sand
Detrital Silt -Sand
Detrital Sand
Sandy Silt
Clay -Silt
Reef
Lake
Land
Island Cres Pilot Project. Croatia
kilometers
0
10

Figure 9. Fisheries in the Island's Area

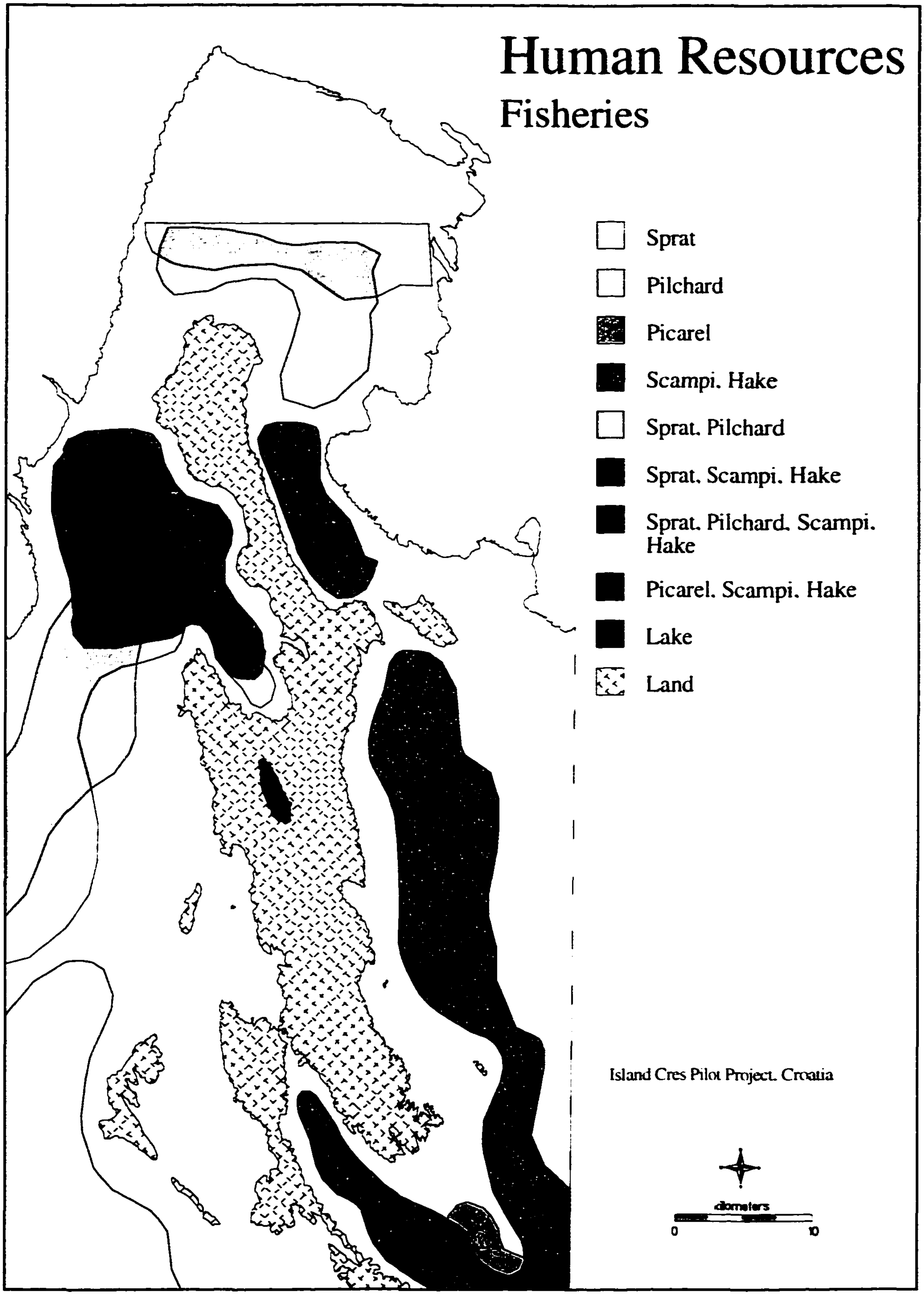

Human Resources
Fisheries
Sprat
Pilchard
Picarel
Scampi. Hake
Sprat. Pilchard
Sprat. Scampi. Hake
Sprat. Pilchard. Scampi. Hake
Picarel. Scampi. Hake
Lake
Land
Island Cres Pilot Project. Croatia
kilometers
0
10

Figure 10. Hydrogeology of the Island

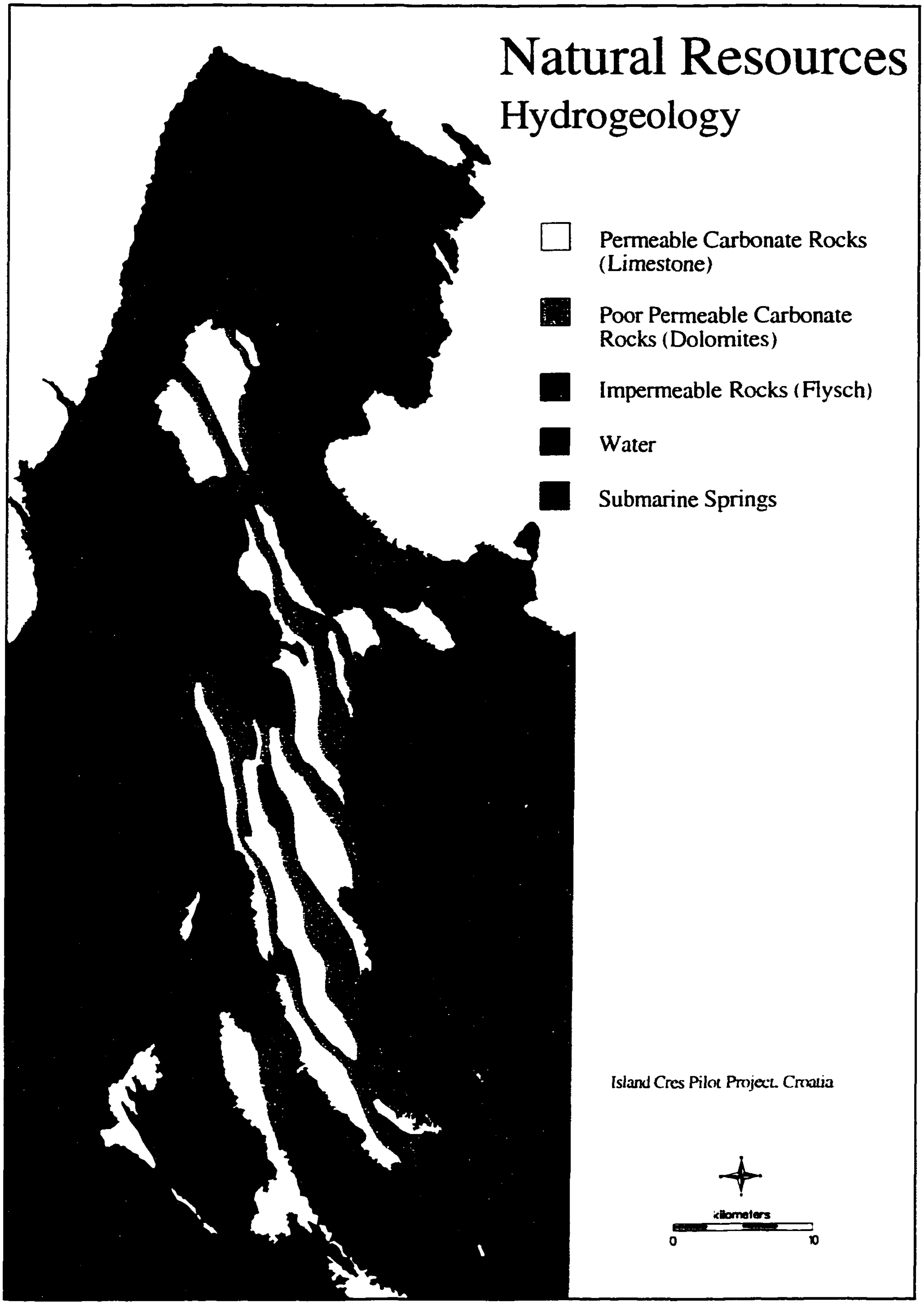

Natural Resources
Hydrogeology
Permeable Carbonate Rocks (Limestone)
Poor Permeable Carbonate Rocks (Dolomites)
Impermeable Rocks (Flysch)
Water
Submarine Springs
Island Cres Pilot Project. Croatia
kilometers
0
10

Figure 11. Two Types of the Island's Vegetation

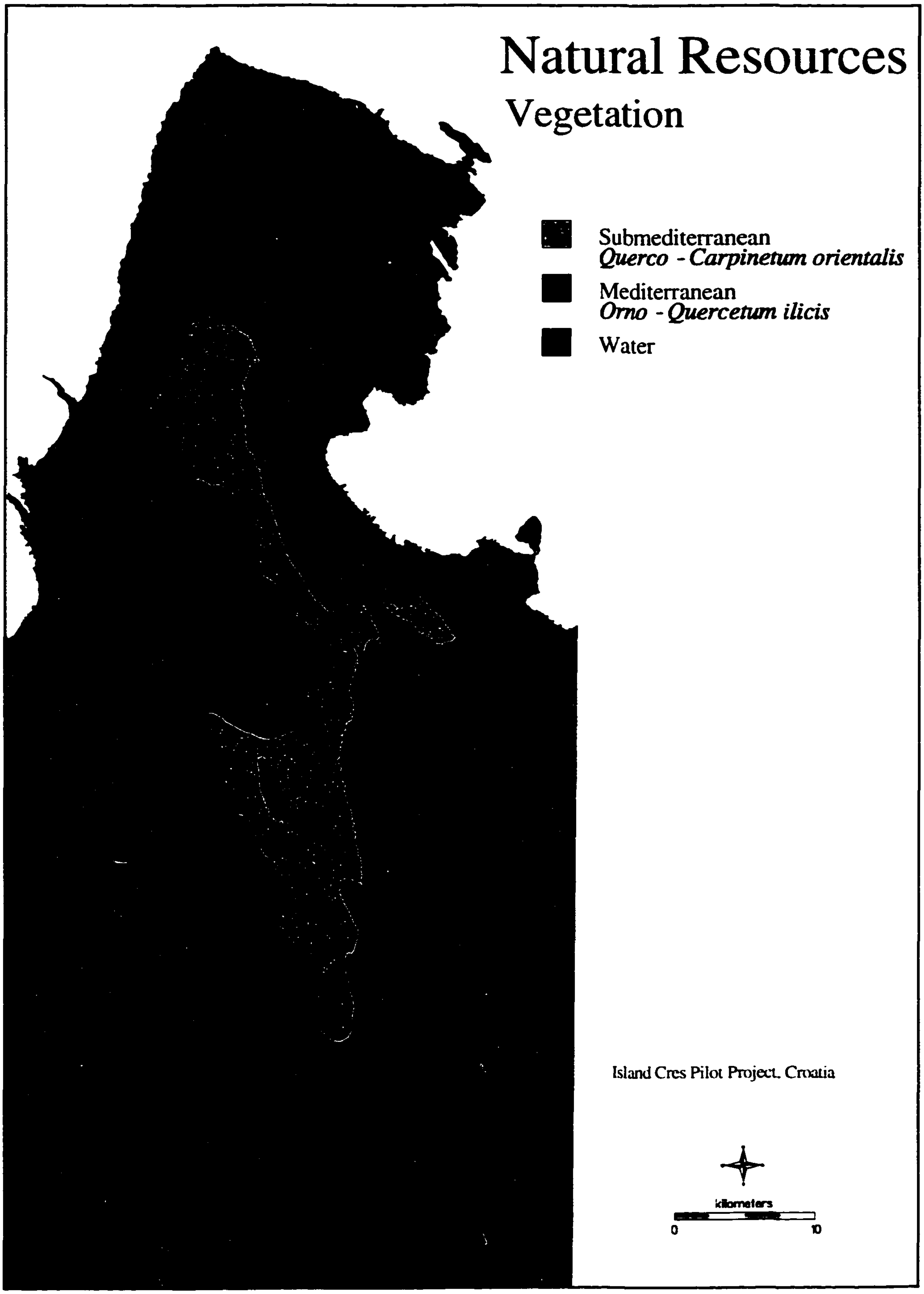
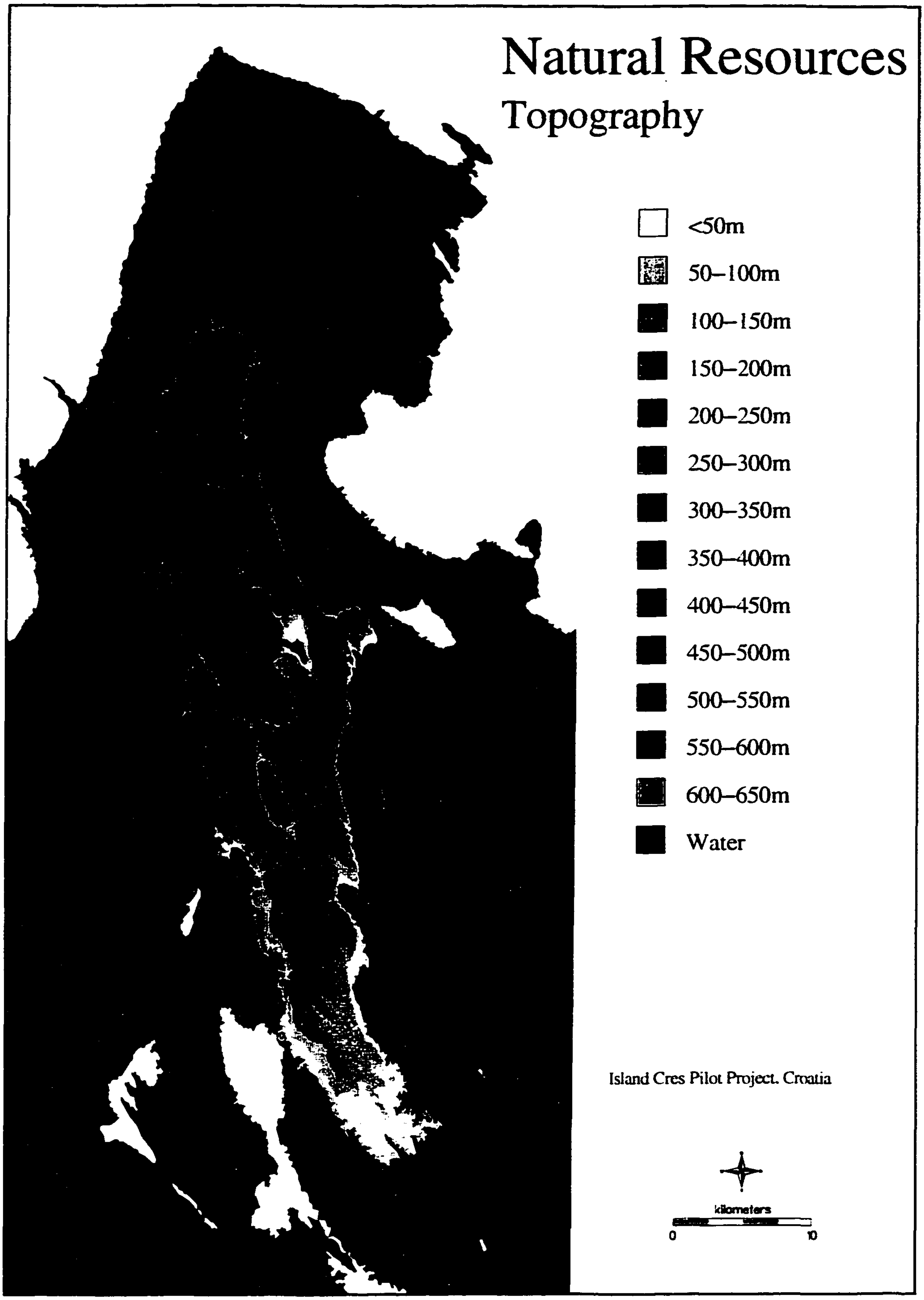
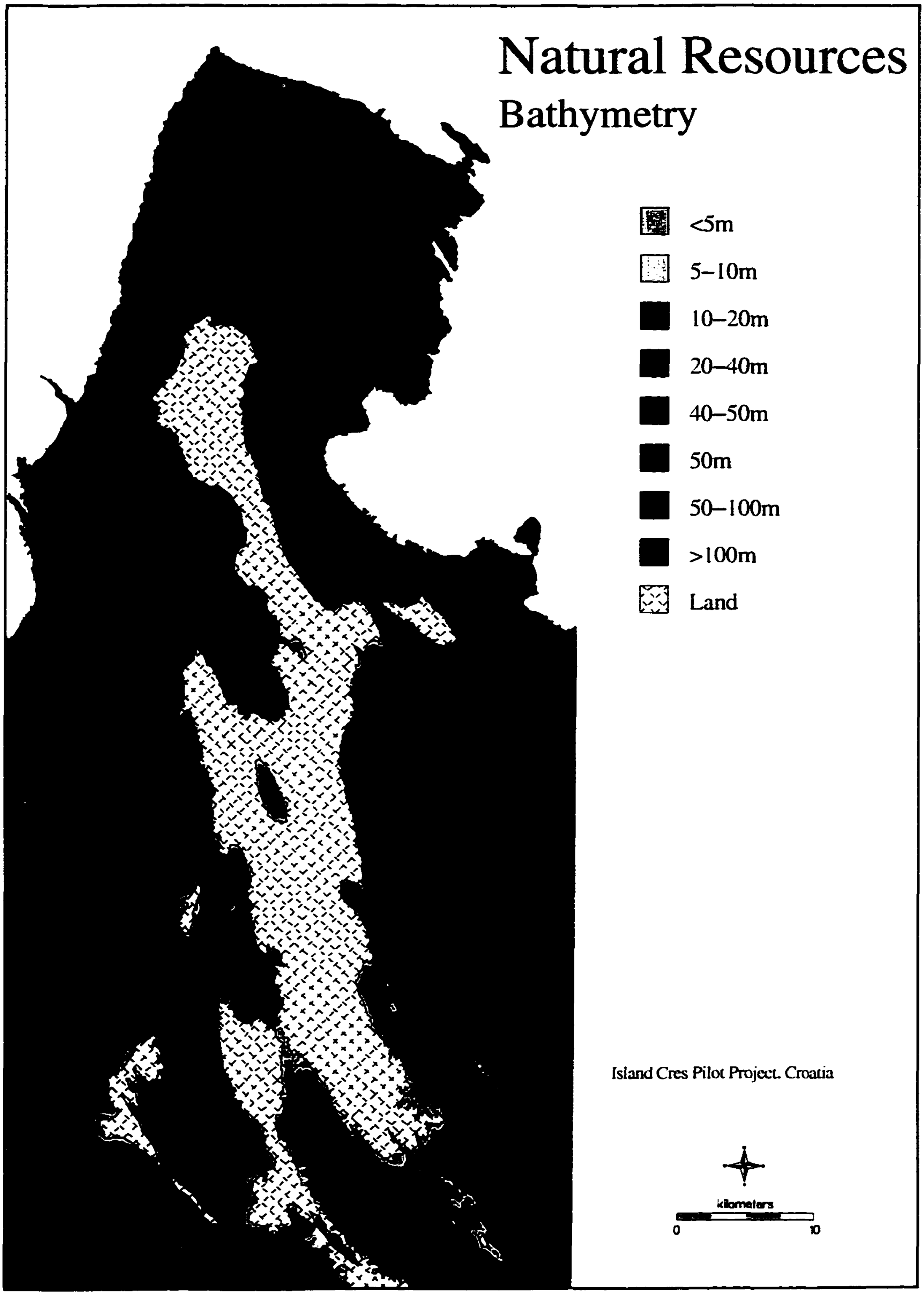

Natural Resources
Vegetation
Submediterranean
Querco - Carpinetum orientalis
Mediterranean
Orno - Quercetum ilicis
Water
Island Cres Pilot Project. Croatia
kilometers
0
10

Figure 12. Topography of the Island



Natural Resources
Topography
<50m
50–100m
100–150m
150–200m
200–250m
250–300m
300–350m
350–400m
400–450m
450–500m
500–550m
550–600m
600–650m
Water
Island Cres Pilot Project. Croatia
kilometers
0
10

Figure 13. Shoreline and Bathymetry of the Island



Natural Resources
Bathymetry
<5m
5–10m
10–20m
20–40m
40–50m
50m
50–100m
>100m
Land
Island Cres Pilot Project. Croatia
kilometers
0
10

Figure 14. Settlements, Roads, Port-Marina, Quarries and Mines on the Island

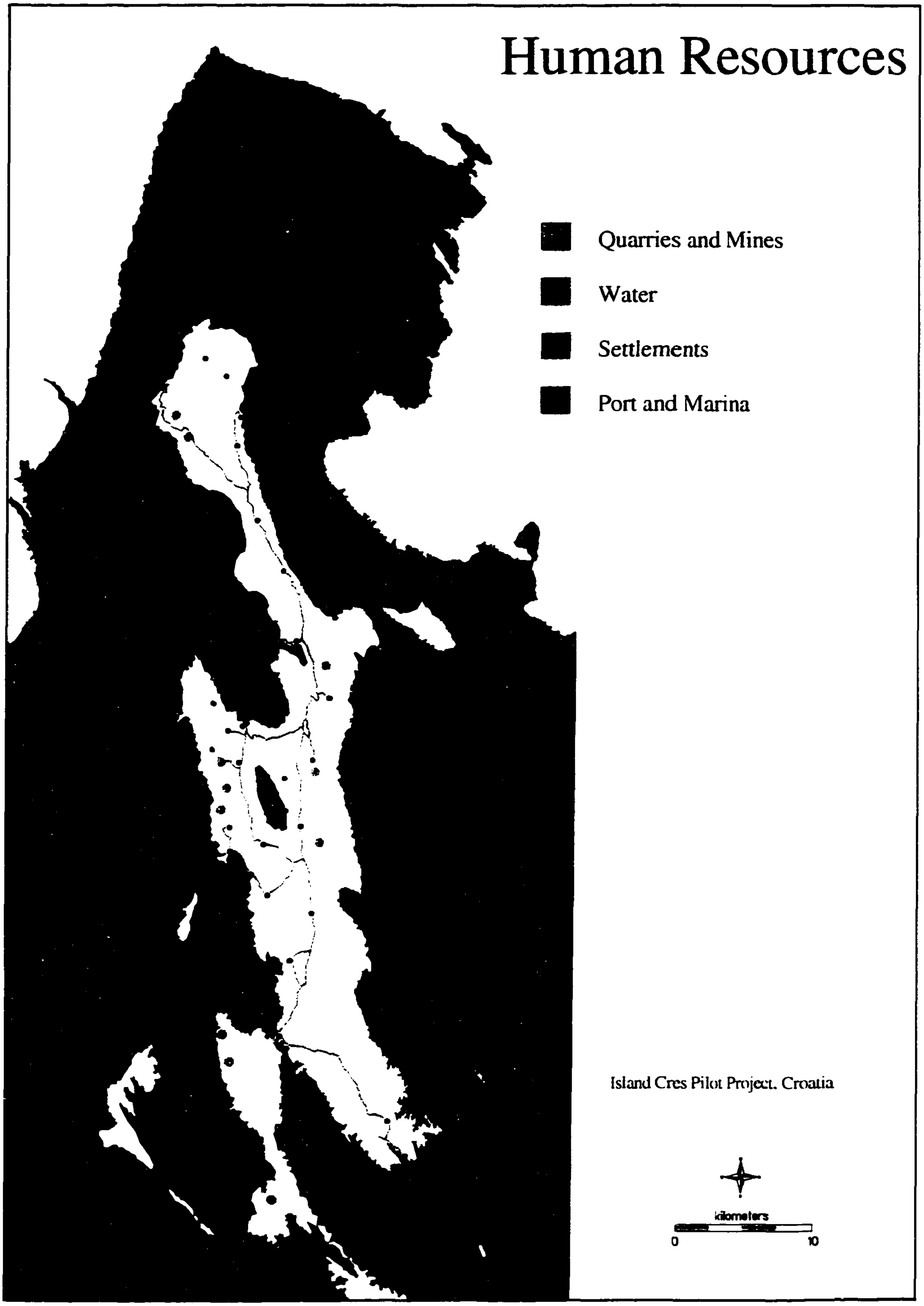

Human Resources
Quarries and Mines
Water
Settlements
Port and Marina
Island Cres Pilot Project, Croatia
kilometers
0
10

Figure 15. DTM – Tin Model of the Island

Digital Terrain Model - TIN of the Island Pilot Project

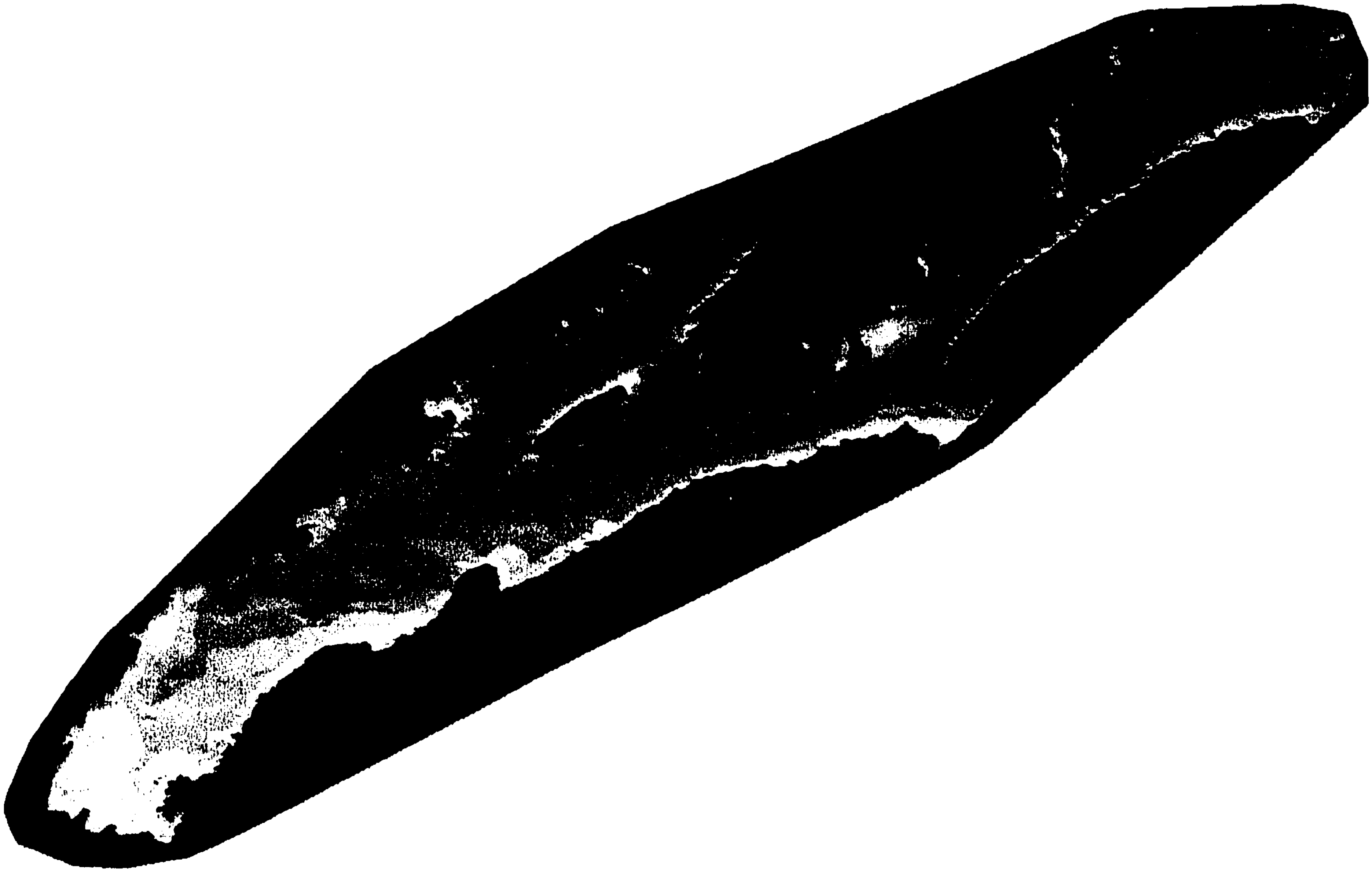
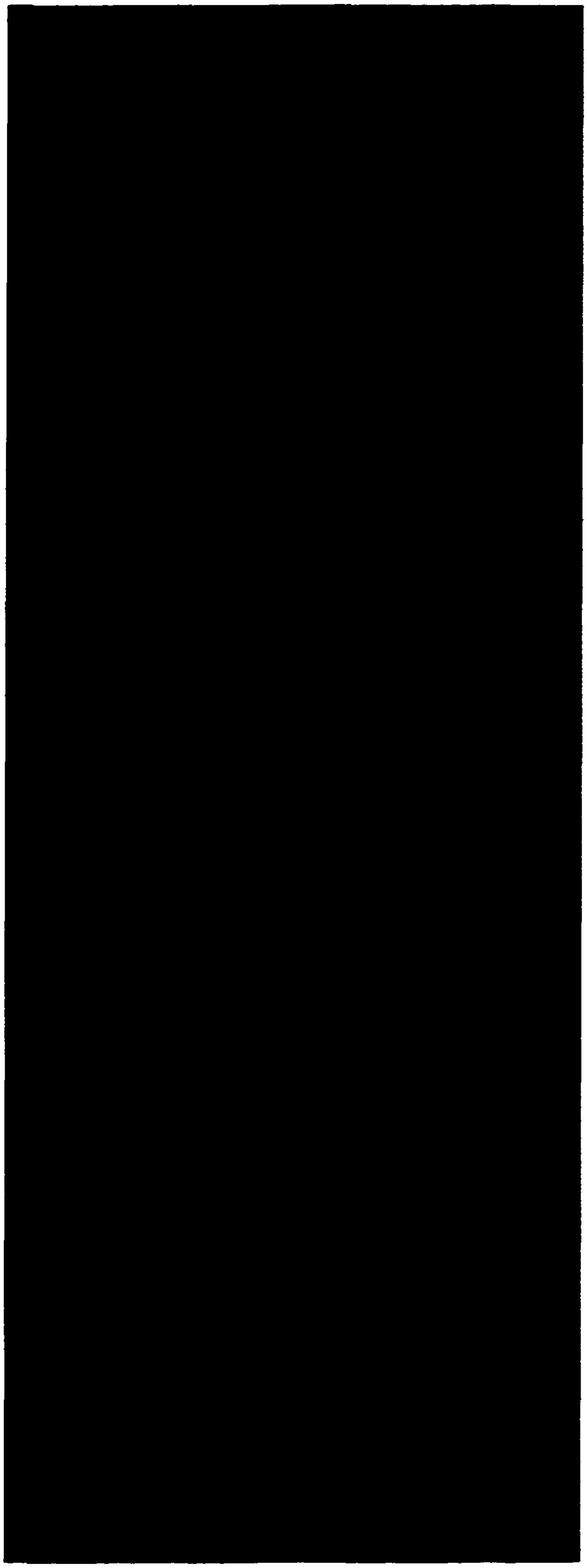


Figure 16. Landsat TM Image of the Island

Figure 17. Landsat TM Image (Band 4) and Island's Shoreline



GIS Shoreline Coverage Landsat TM Band 4

Island Cres Pilot Project

For this shoreline process a seed pixel was chosen at random in the water area. The parameters were set at 8 neighbours which allows growing in all directions. The spectral Euclidean distance from the mean of the seed pixel was 41.

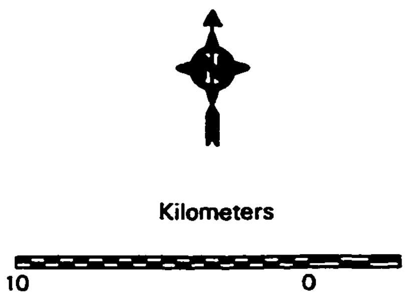


Figure 18. Potential Aquaculture Sites of the Island

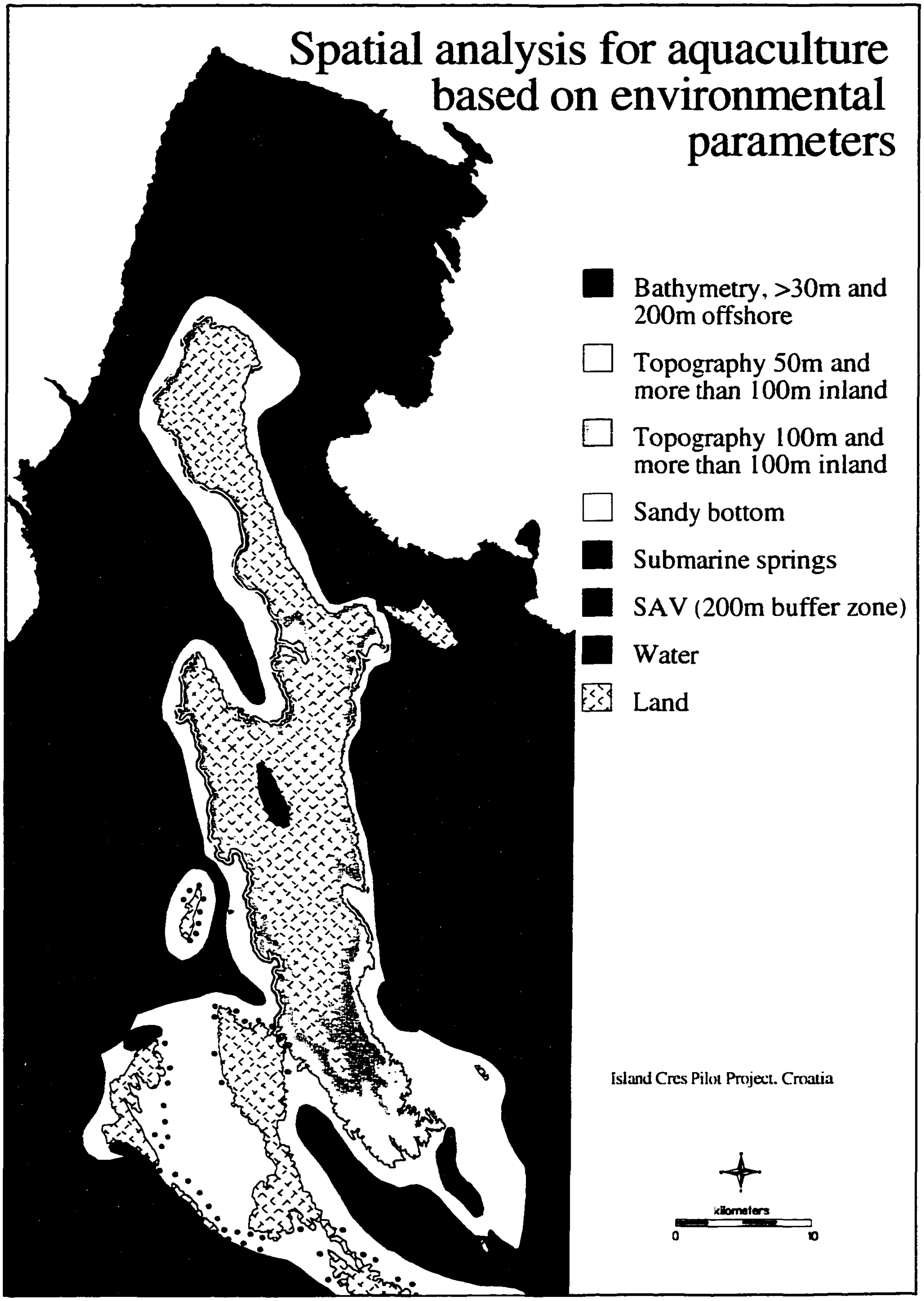
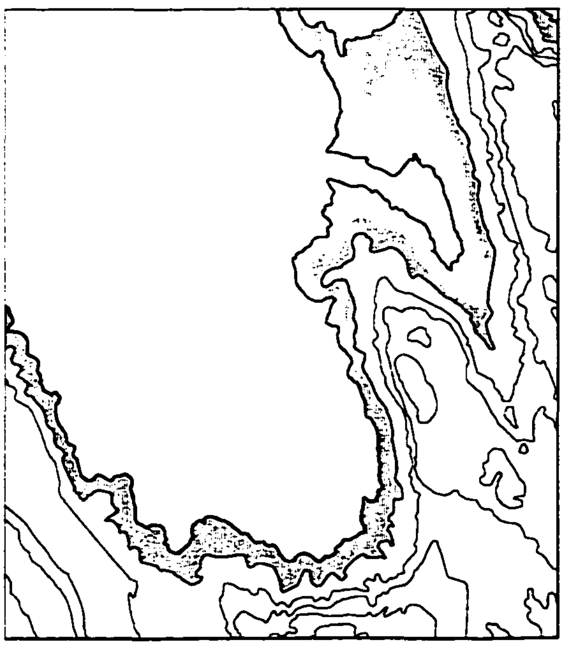

Spatial analysis for aquaculture based on environmental parameters
Bathymetry, >30m and 200m offshore
Topography 50m and more than 100m inland
Topography 100m and more than 100m inland
Sandy bottom
Submarine springs
SAV (200m buffer zone)
Water
Land
Island Cres Pilot Project, Croatia
kilometers
0
10

Figure 19. Spatial Analysis for Aquaculture Based on Natural Resources (I)

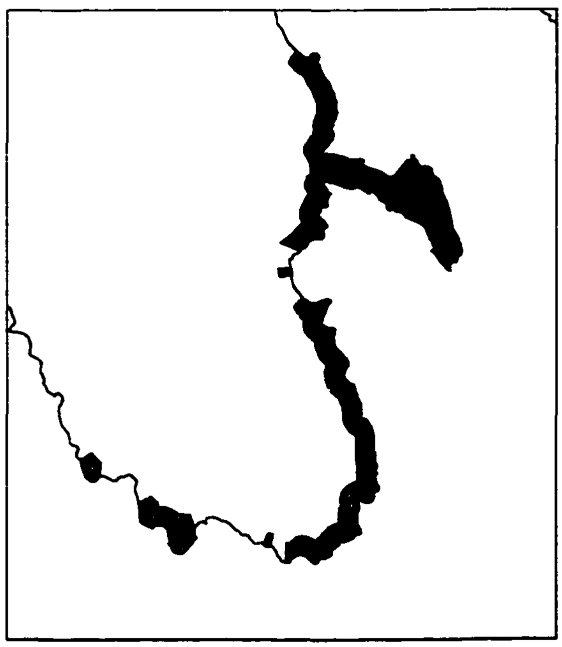
Spatial analysis for aquaculture based on natural resources (I)

1. 200m and 300m buffer offshore and 100m buffer inland

2. Selected polygons of suitable bathymetry areas. >30m ■



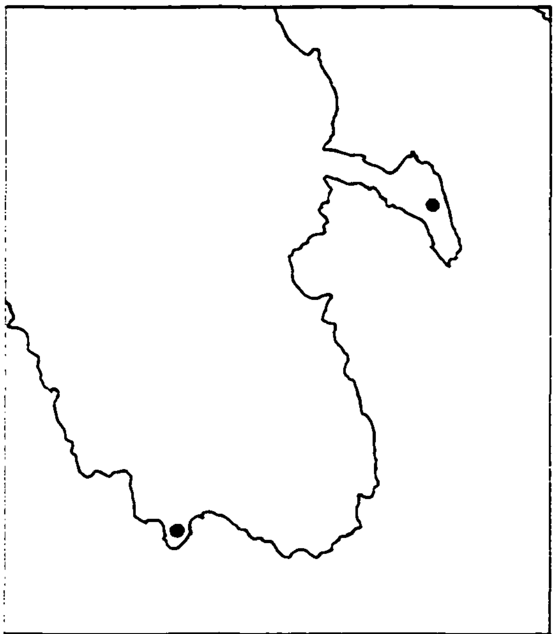
3. Selected polygons of suitable topography areas. 50m 100m



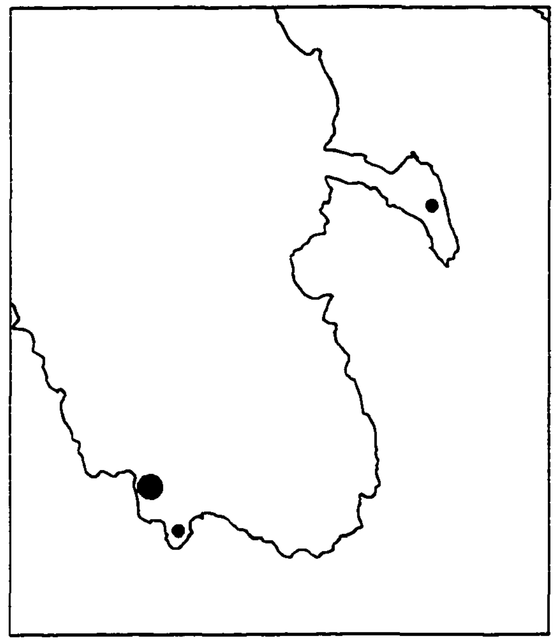
4. Suitable areas based on topography and bathymetry. good ■ medium ■

Figure 20. Spatial Analysis for Aquaculture Based on Natural Resources (II)

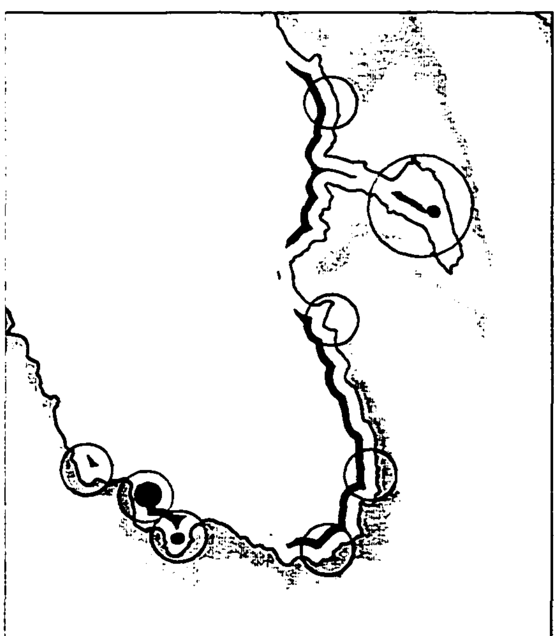
Spatial analysis for aquaculture based on natural resources (II)



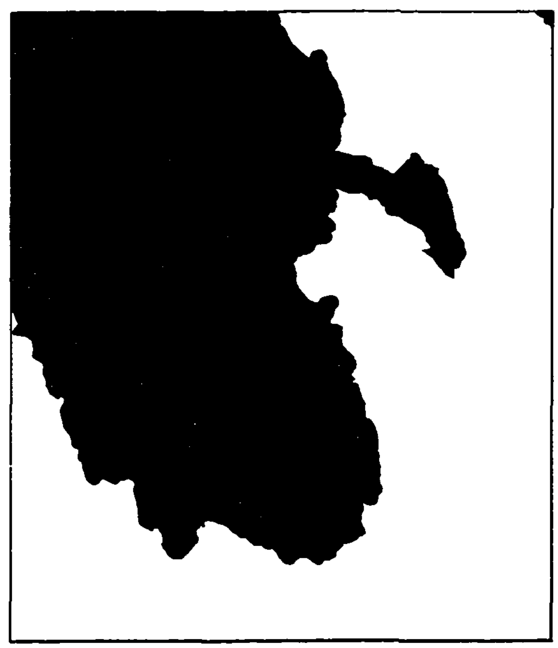
5. Selected polygons of suitable benthic substrate, and submarine springs ■



6. Selected polygon of SAV ■ as unsuitable site



7. Spatial analysis showing good ○ medium ○ poor ○ and unsuitable ○ areas for aquaculture



8. Shoreline areas selected for potential aquaculture activities

Figure 21. Potential Aquaculture Sites Based on Natural Resources

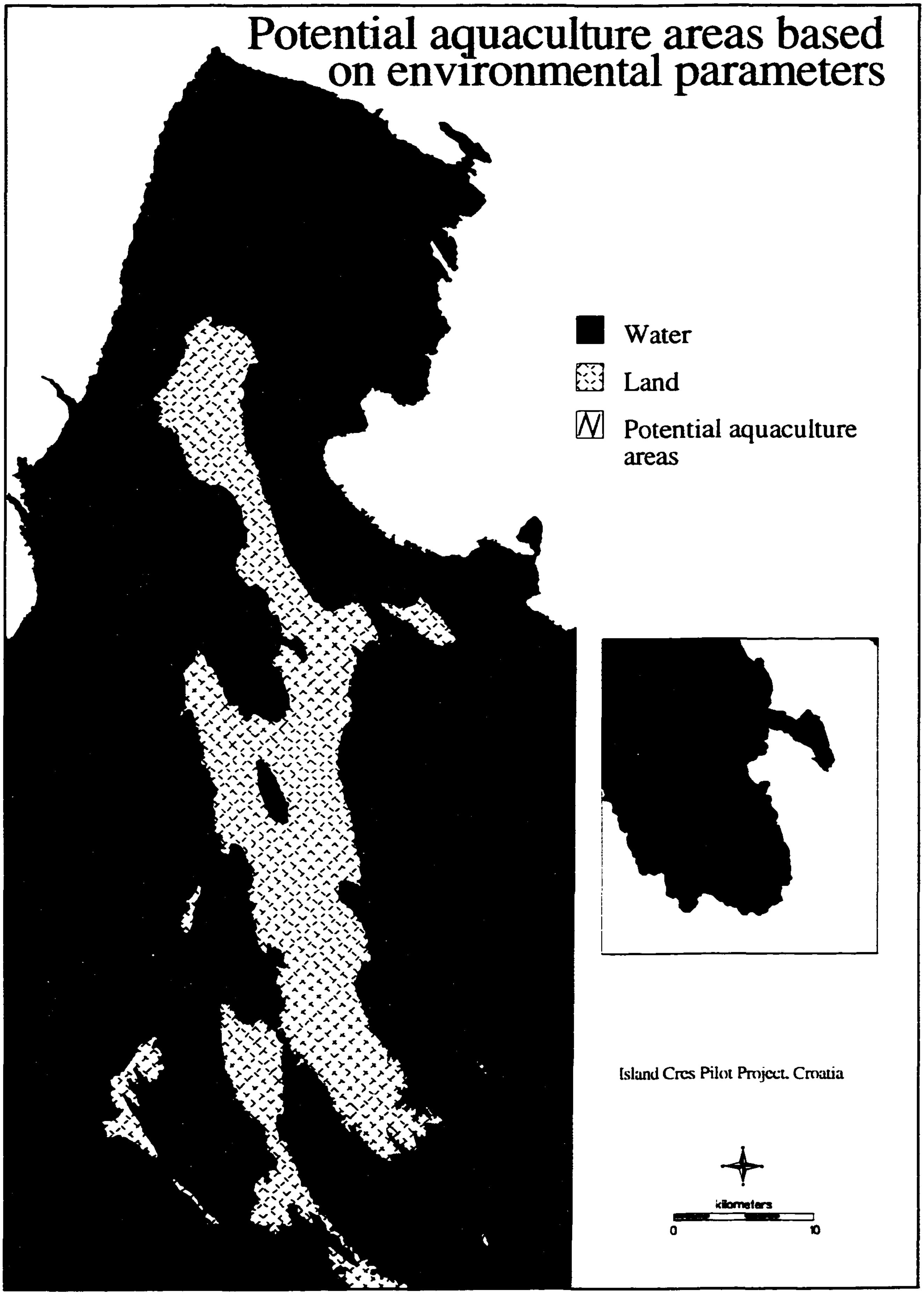
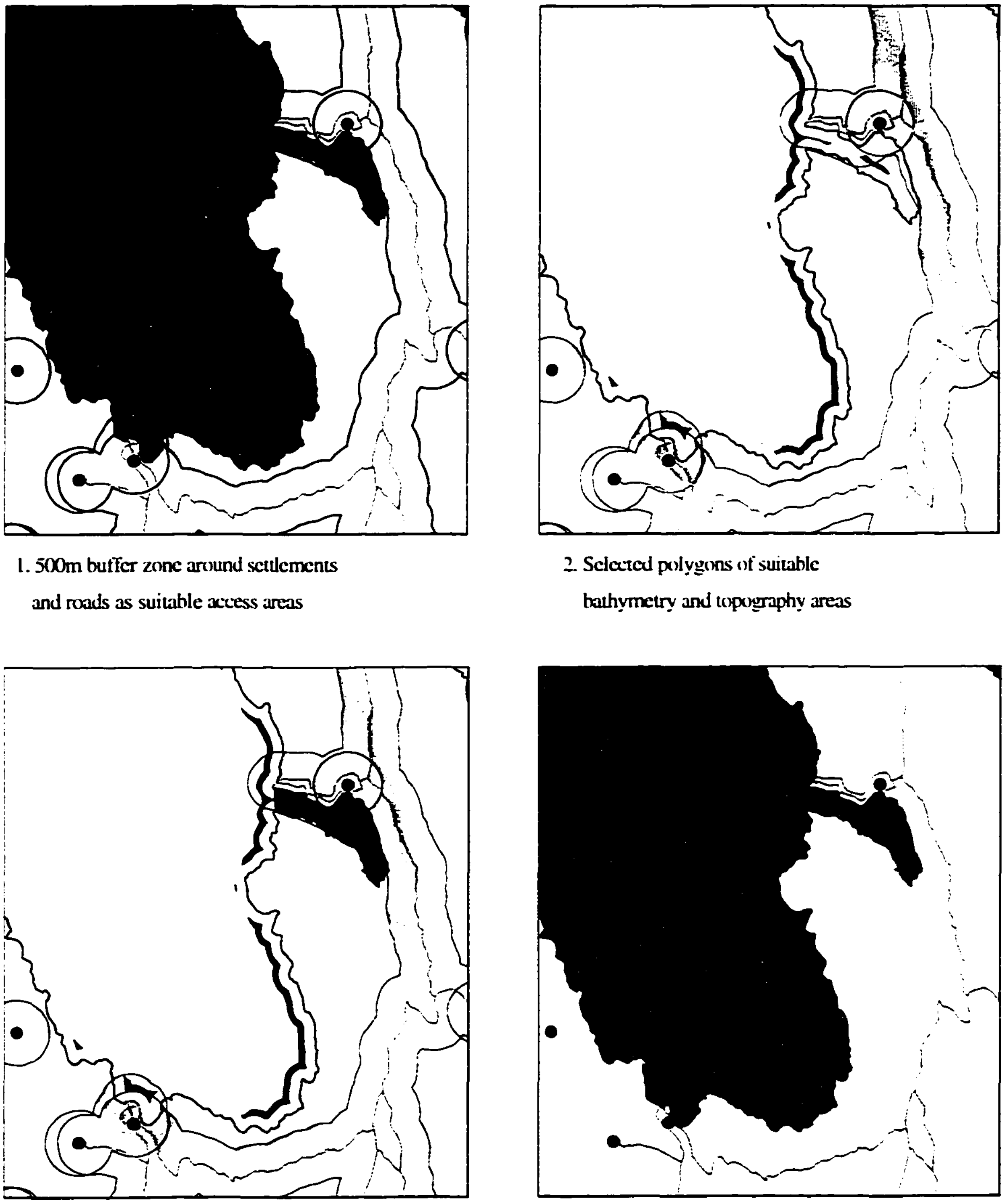

Potential aquaculture areas based on environmental parameters
Water
Land
Potential aquaculture areas
Island Cres Pilot Project, Croatia
kilometers
0
10

Figure 22. Spatial Analysis for Aquaculture Based on Human Resources

Spatial analysis for aquaculture based on human resources



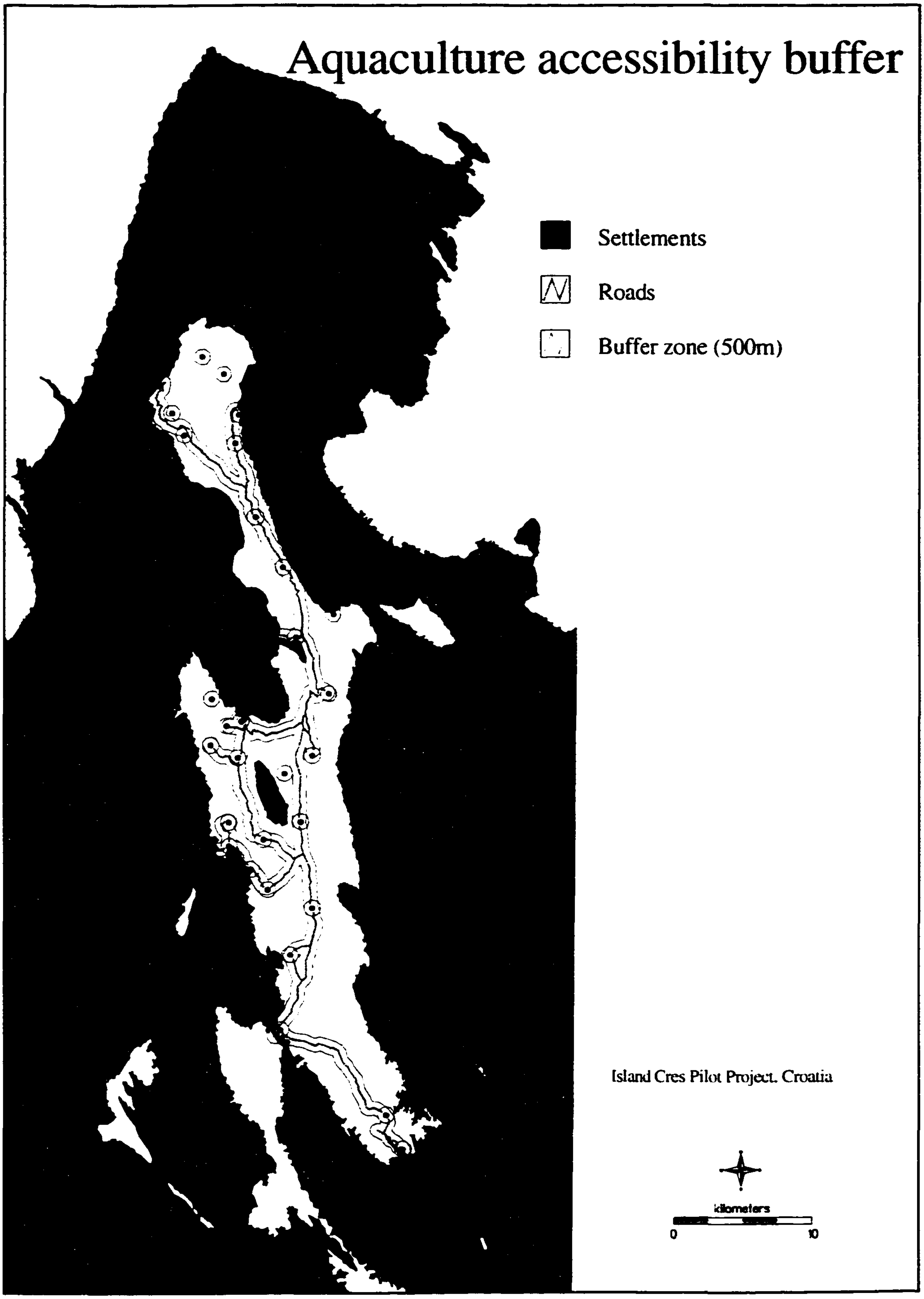
1. 500m buffer zone around settlements and roads as suitable access areas

2. Selected polygons of suitable bathymetry and topography areas

3. Selected polygons of unsuitable water quality area ■

4. Shoreline areas selected for potential aquaculture activities

Figure 23. Aquaculture Accessibility Buffer



Aquaculture accessibility buffer
Settlements
Roads
Buffer zone (500m)
Island Cres Pilot Project. Croatia
kilometers
0
10

Figure 24. Potential Aquaculture Sites Based on Human Resources

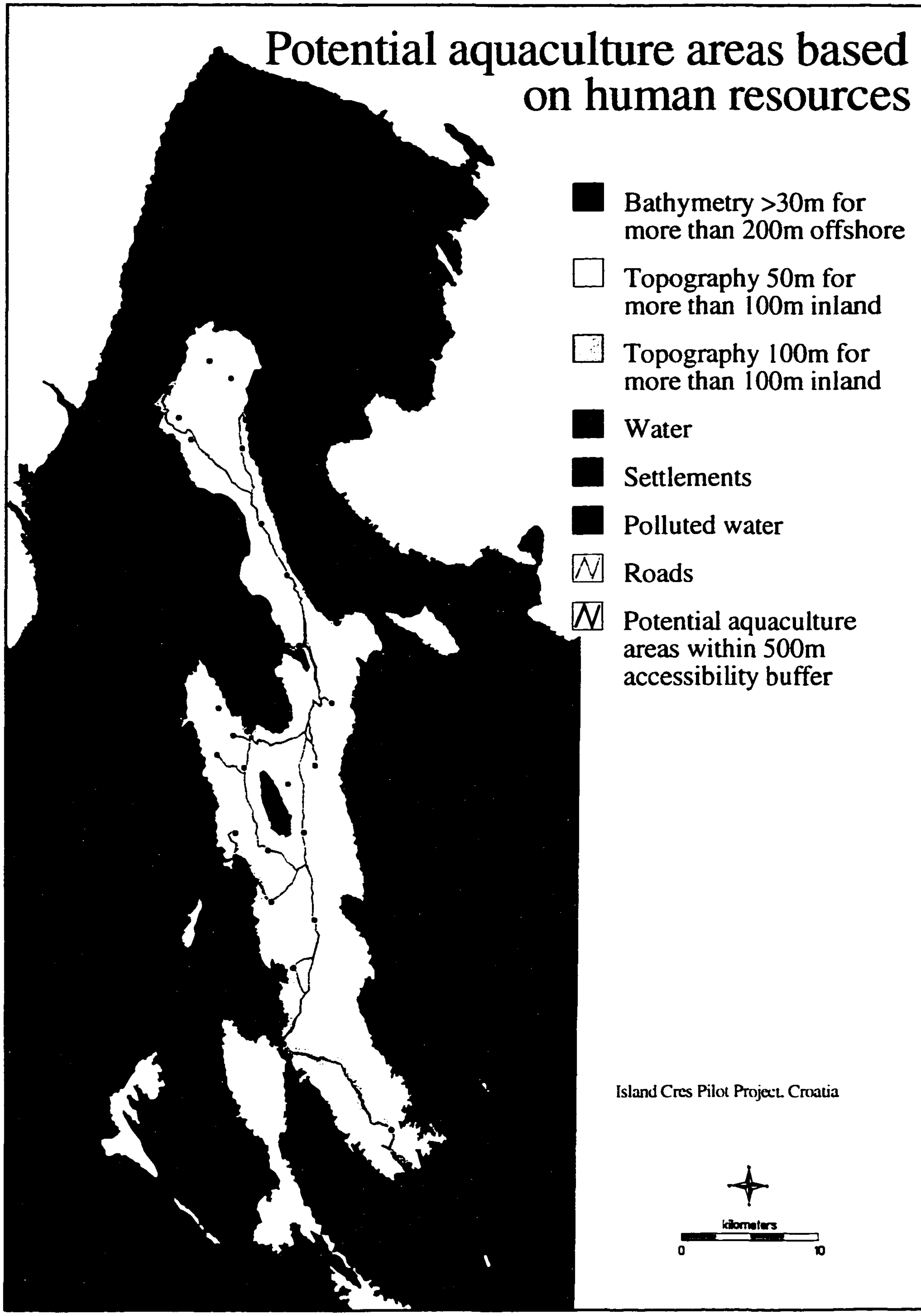

Potential aquaculture areas based on human resources
Bathymetry >30m for more than 200m offshore
Topography 50m for more than 100m inland
Topography 100m for more than 100m inland
Water
Settlements
Polluted water
Roads
Potential aquaculture areas within 500m accessibility buffer
Island Cres Pilot Project. Croatia
kilometers
0
10

Figure 25. Potential Aquaculture sites based on natural and human resources

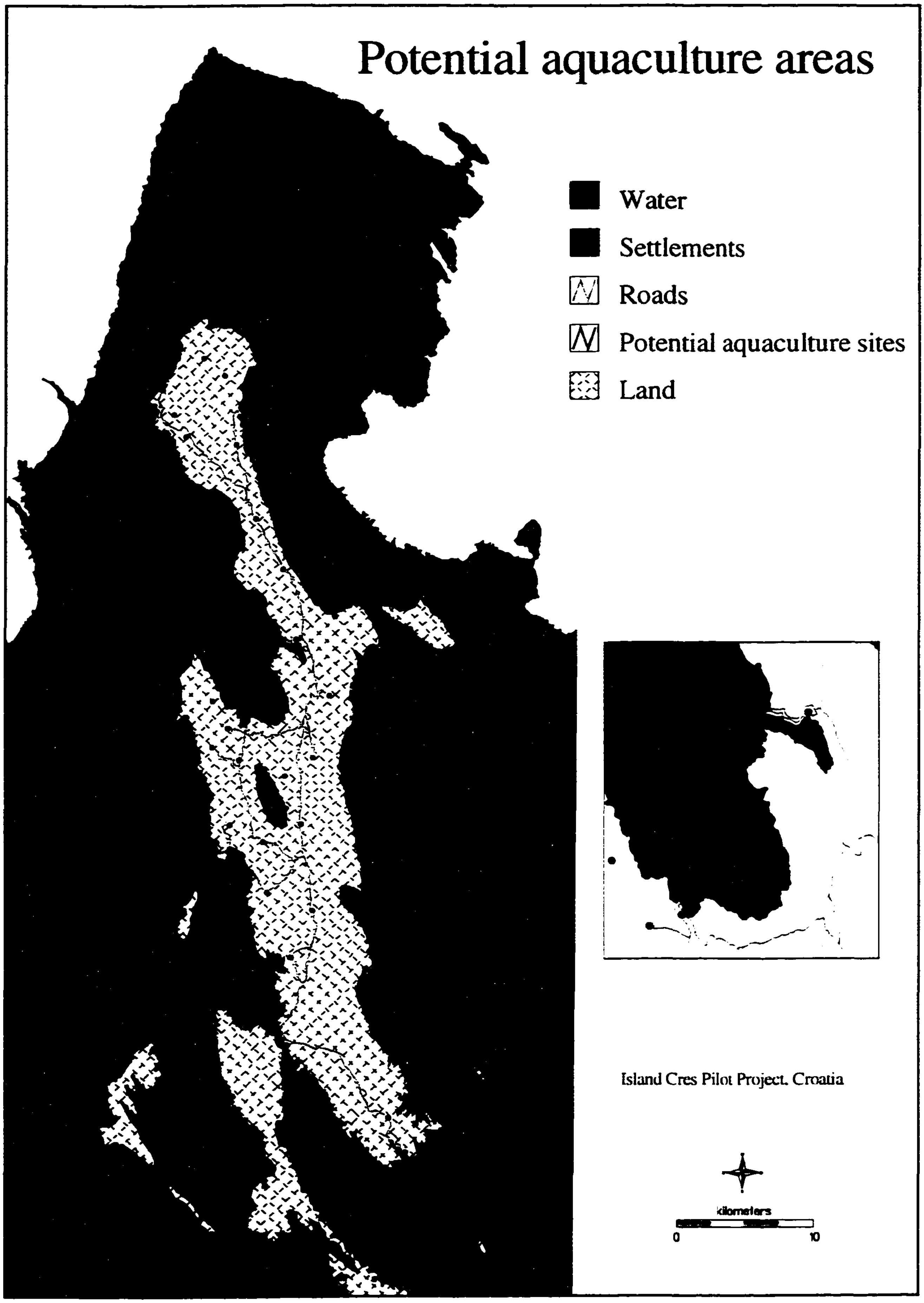
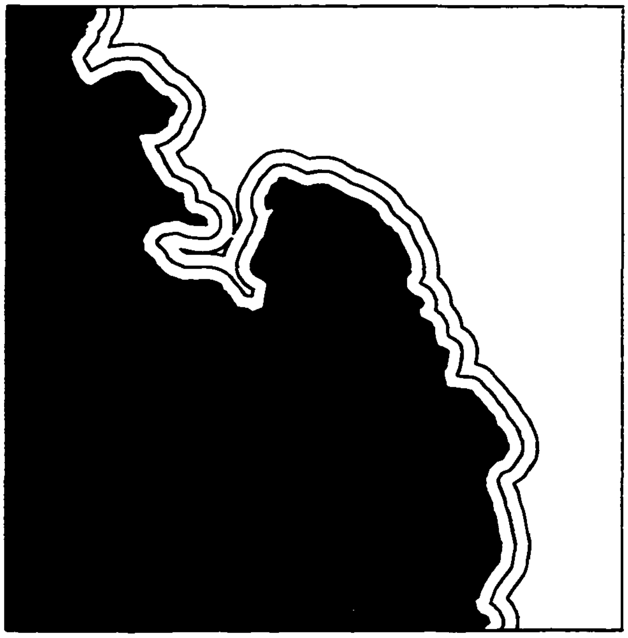
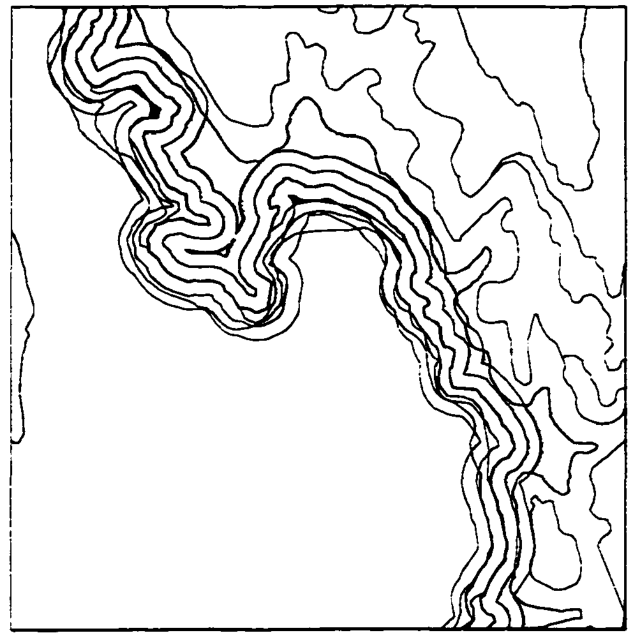

Potential aquaculture areas
Water
Settlements
Roads
Potential aquaculture sites
Land
Island Cres Pilot Project, Croatia
kilometers
0
10

Figure 26. Spatial Analysis for Beach Areas Based on Natural Resources

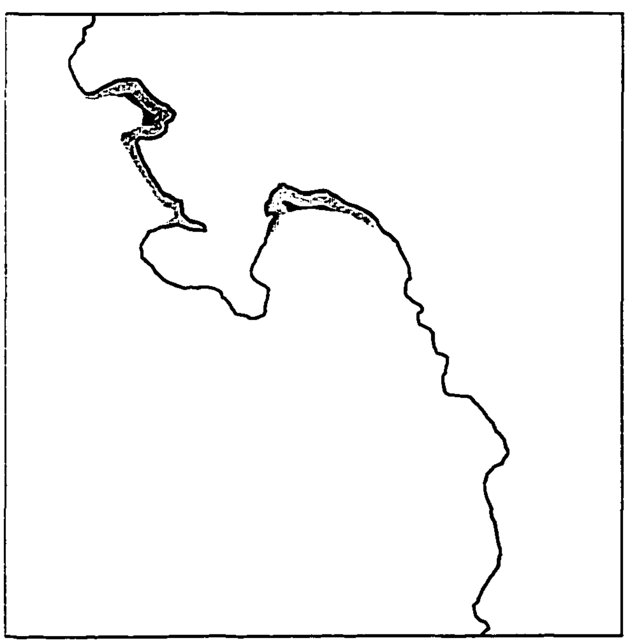
Spatial analysis for beach areas based on natural resources



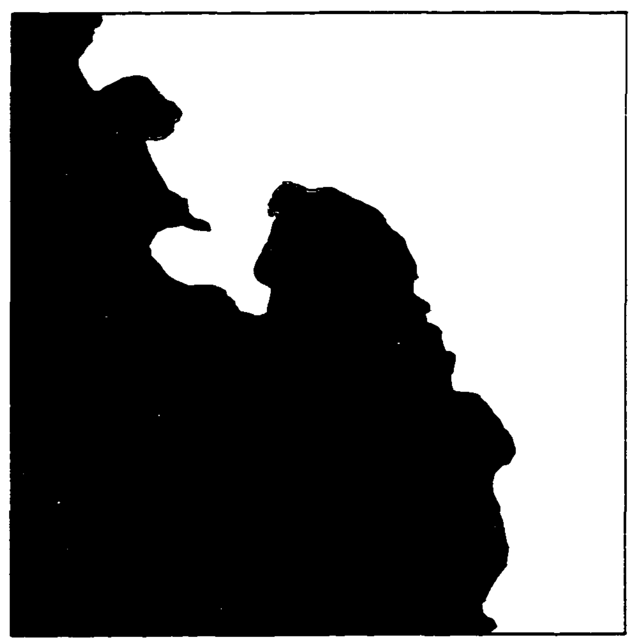
1. 100m and 200m buffer offshore and inland



2. Selected polygons of suitable bathymetry and topography areas

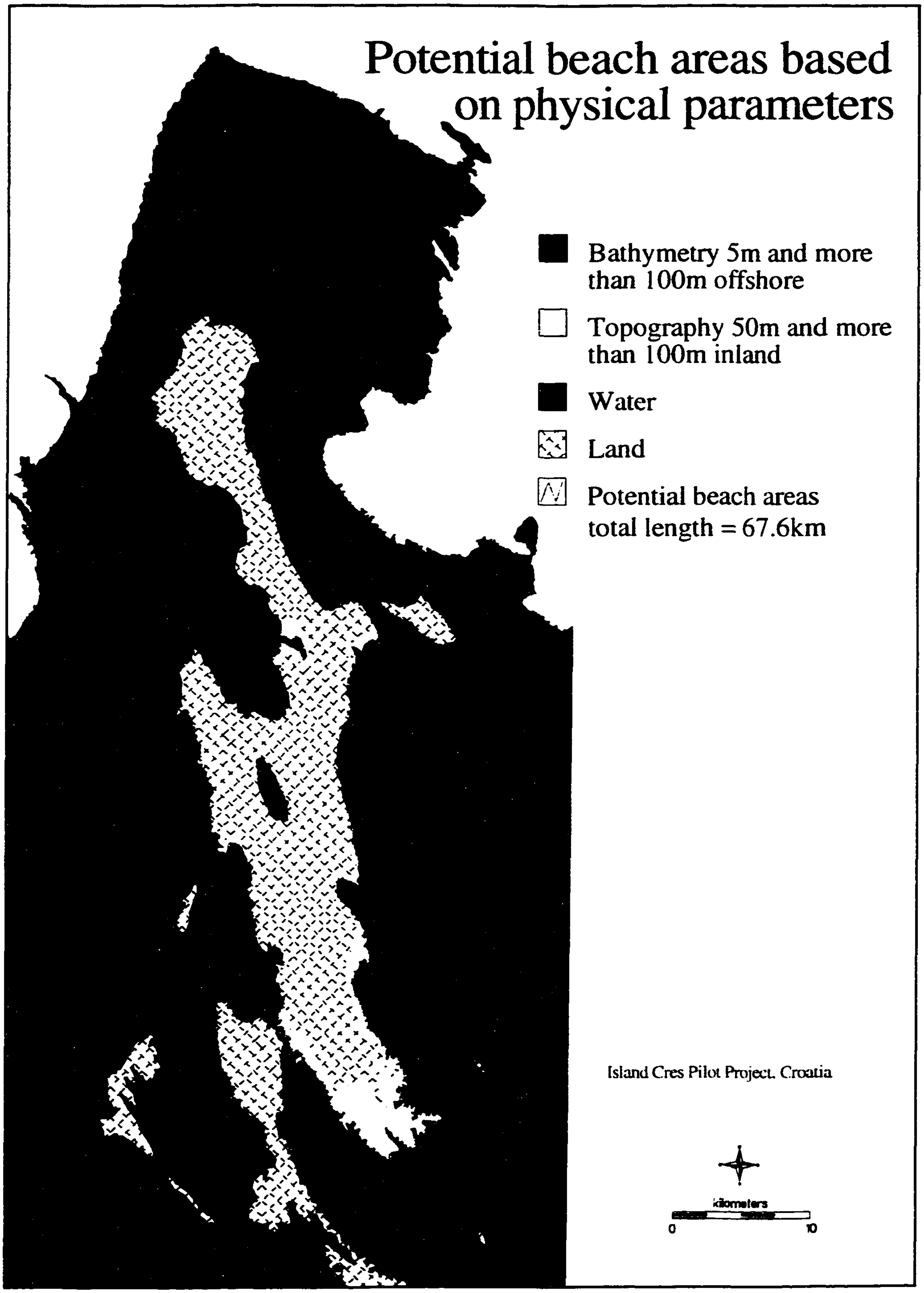


3. Selected polygons of 5m bathymetry and sandy benthos



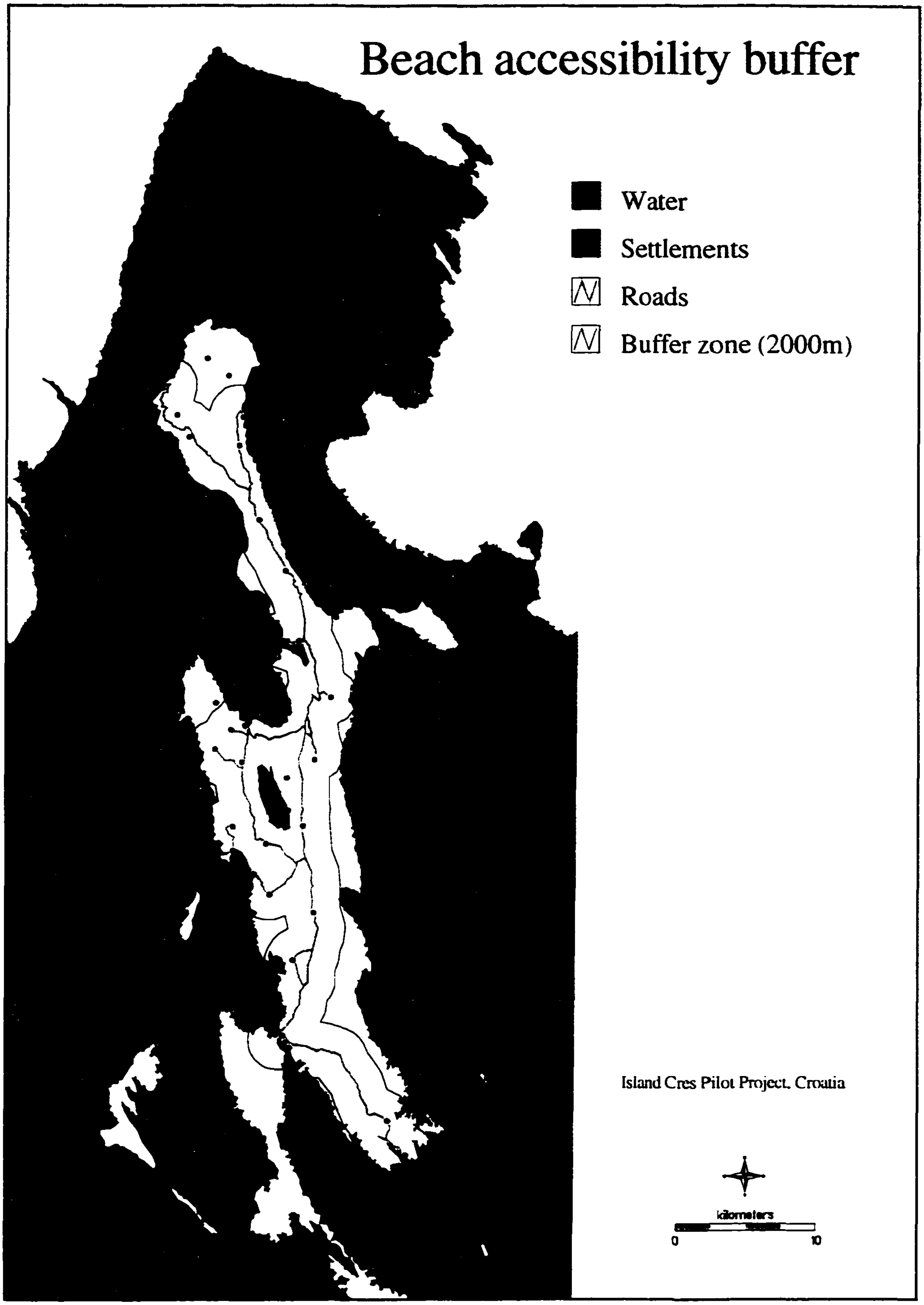
4. Potential beach areas

Figure 27. Potential Beach Areas Based on Natural Resources



Potential beach areas based on physical parameters
Bathymetry 5m and more than 100m offshore
Topography 50m and more than 100m inland
Water
Land
Potential beach areas total length = 67.6km
Island Cres Pilot Project. Croatia
kilometers
0
10

Figure 28. Potential Beach Areas Based on Human Resources


Beach accessibility buffer
Water
Settlements
Roads
Buffer zone (2000m)
Island Cres Pilot Project, Croatia
kilometers
0
10

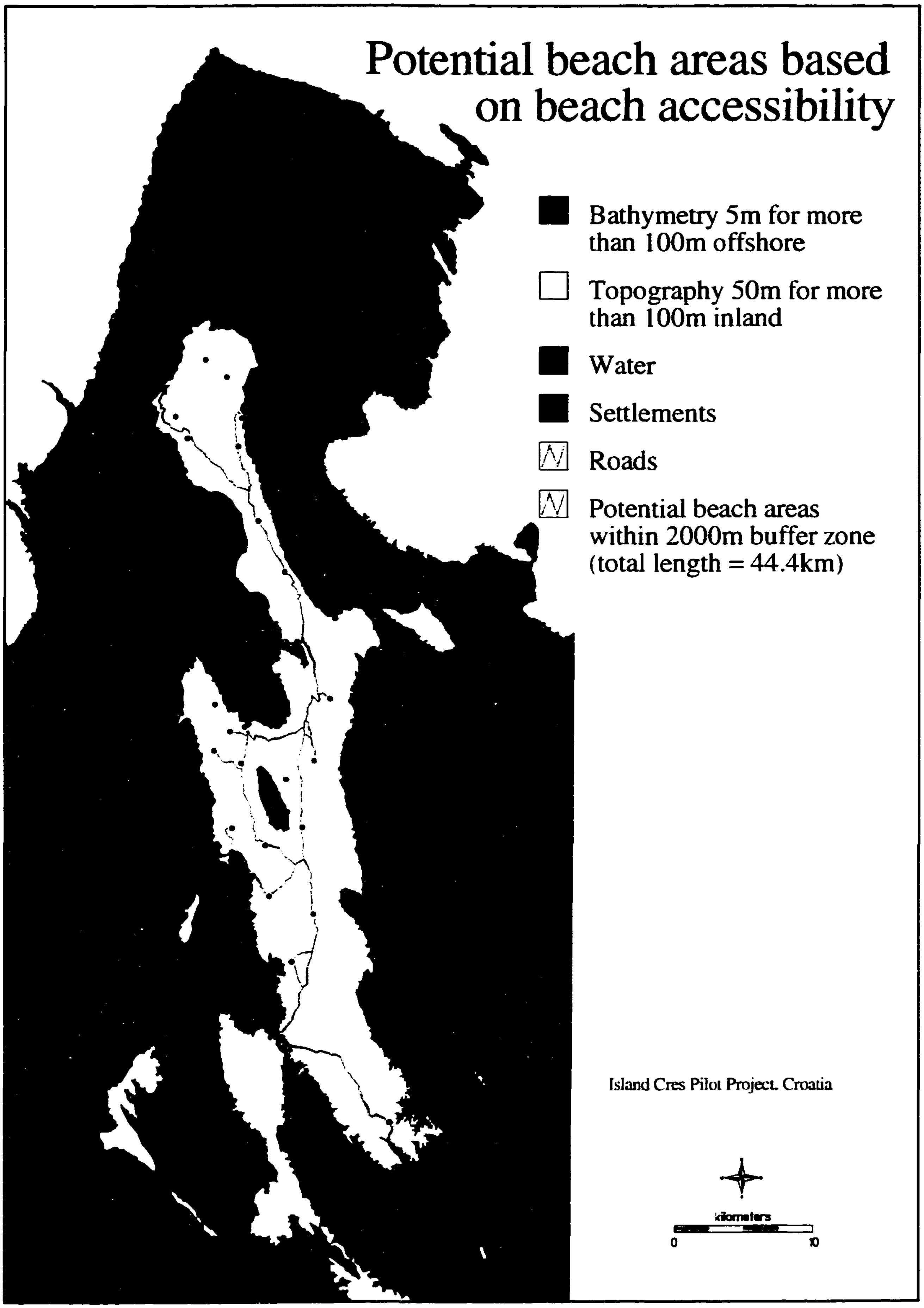
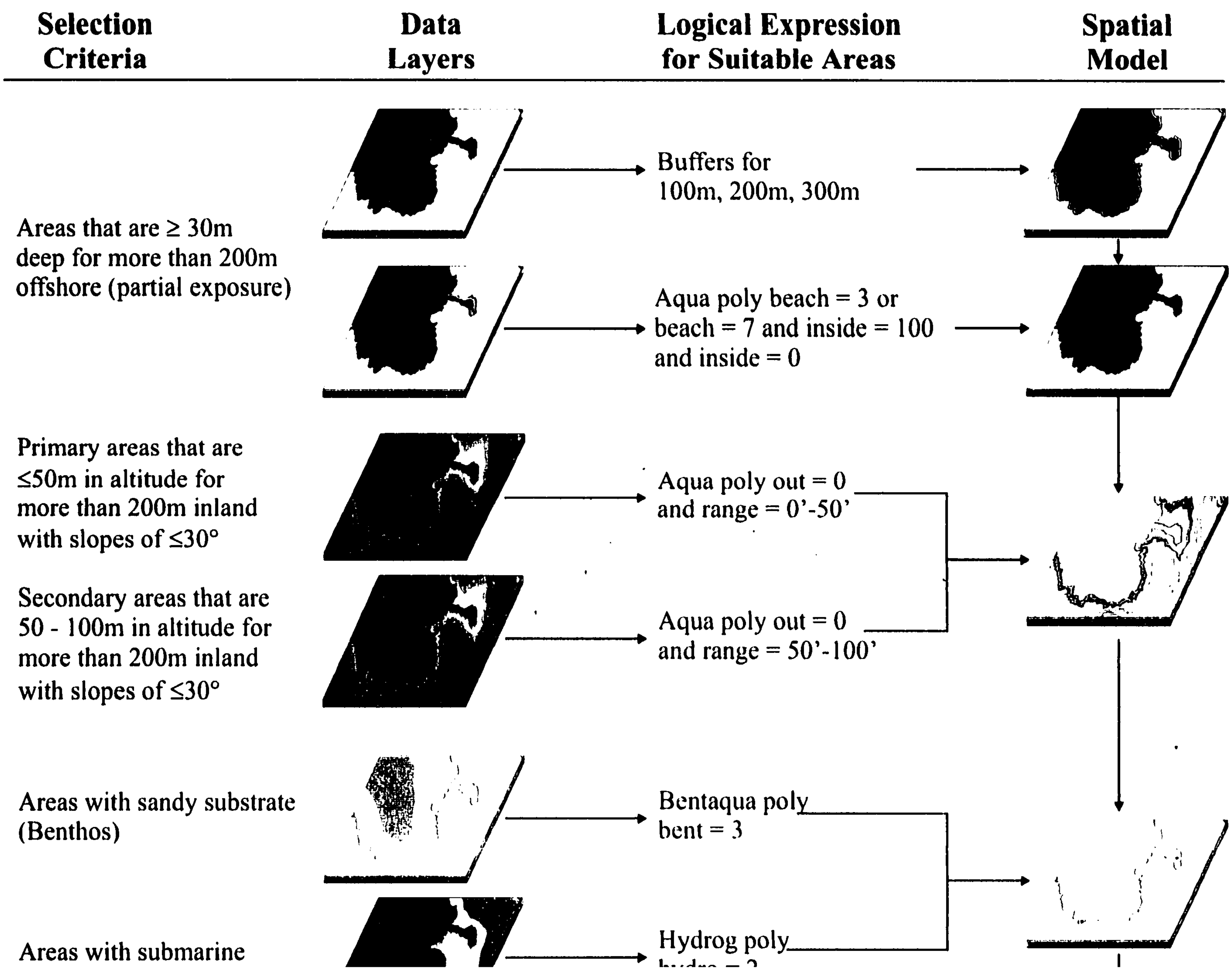

Potential beach areas based on beach accessibility
Bathymetry 5m for more than 100m offshore
Topography 50m for more than 100m inland
Water
Settlements
Roads
Potential beach areas within 2000m buffer zone (total length = 44.4km)
Island Cres Pilot Project. Croatia
kilometers
0
10

Figure 29. Spatial Analysis Performance for the Aquaculture

Performing the Spatial Analysis for Aquaculture



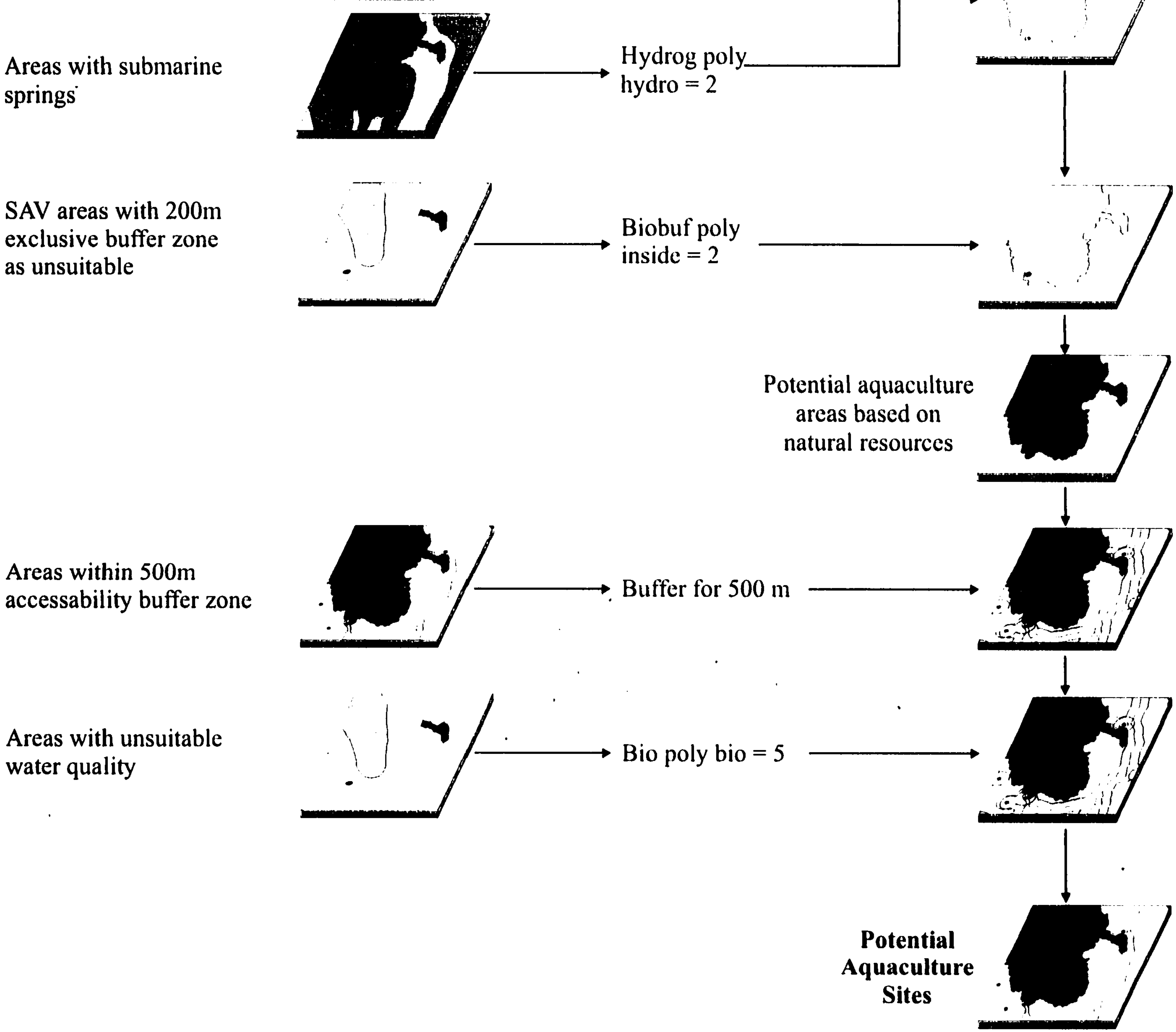

Areas with submarine springs
Hydrog poly hydro = 2
SAV areas with 200m exclusive buffer zone as unsuitable
Biobuf poly inside = 2
Potential aquaculture areas based on natural resources
Areas within 500m accessability buffer zone
Buffer for 500 m
Areas with unsuitable water quality
Bio poly bio = 5
Potential Aquaculture Sites

Figure 30. Spatial Use Conflict Analysis for Potential Aquaculture Development

Spatial Use Conflict Analysis for Aquaculture

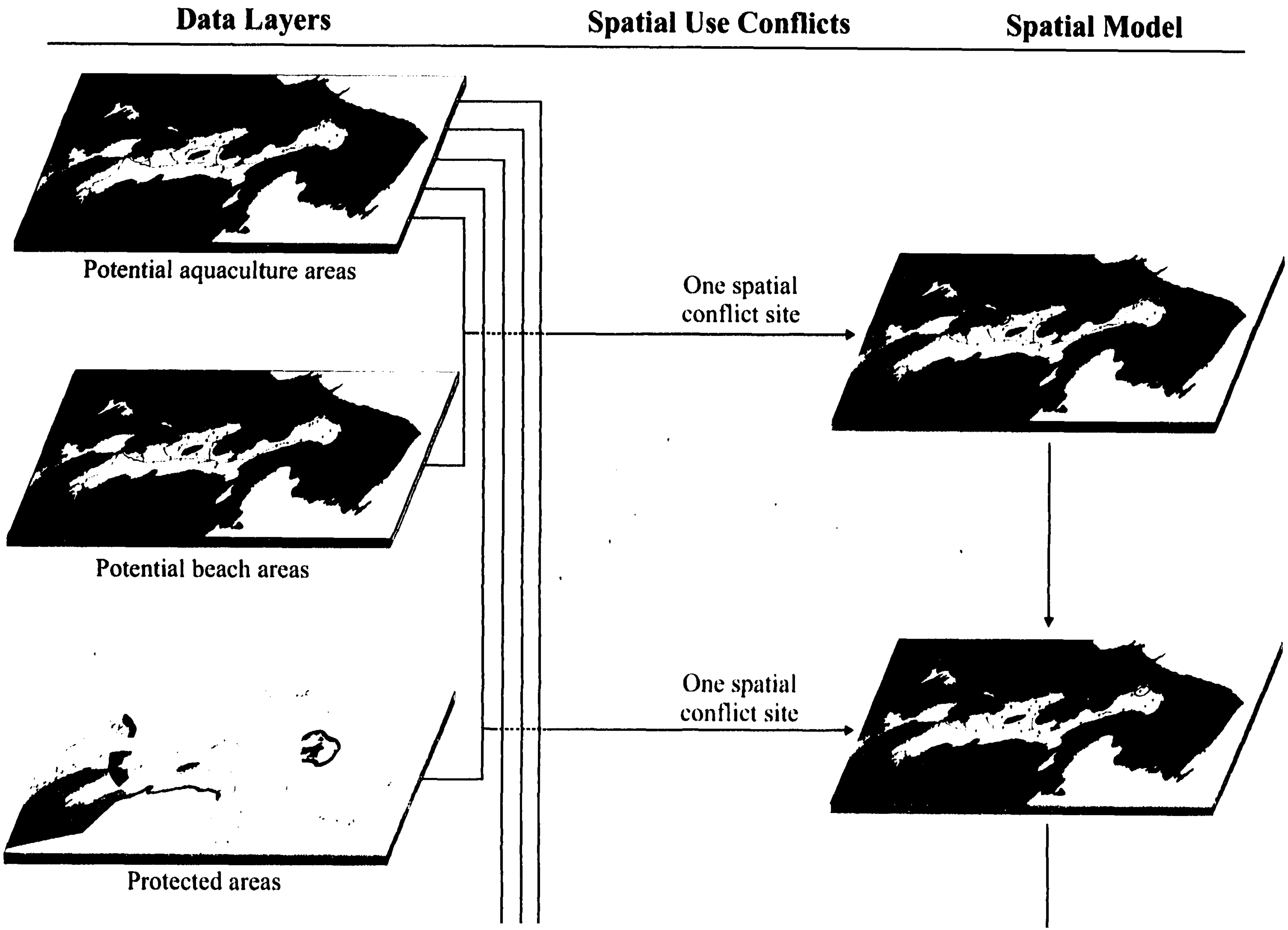


Figure 31. Spatial Use Conflict Analysis for Ecotourism Development
(Beach Areas)

Spatial Use Conflict Analysis for Beach Areas

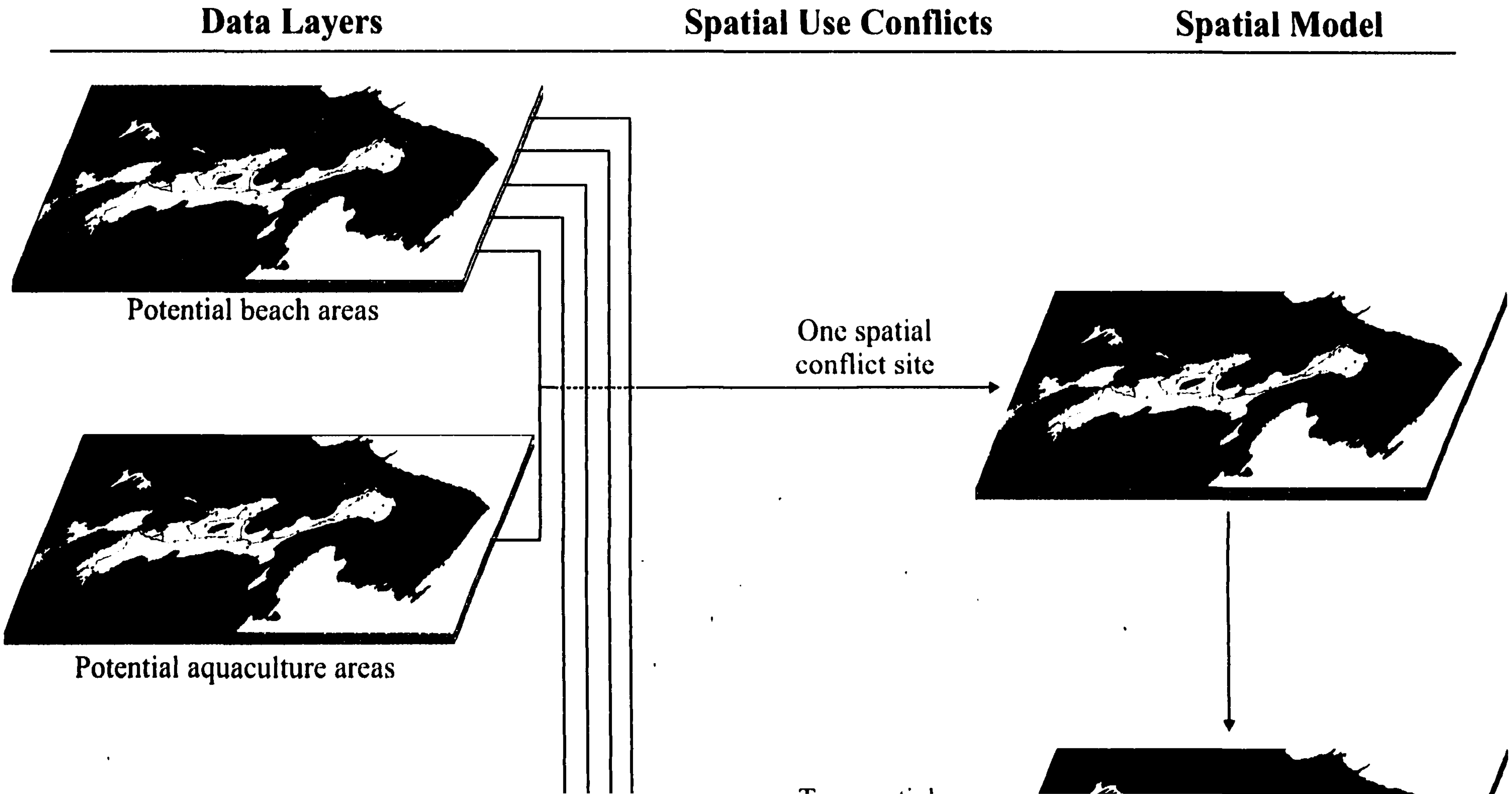


Table1. **Natural Characteristics of the Island Cres**

Surface area	404.33 km^2
Coastline length	247.7 km (literature), digitized for this project 280 km
Population	3.238 (1991)
Highest peak	Gorice (650m)
Climate	Mild Mediterranean, low diurnal and seasonal variations, low participation in summer, daily average of 10 sunshine hours, and temperate, rainy winters (900mm)
Land cover	Karst terrain and macchia, pine woods, oak and hornbean forests cover 33%, and pastures 45%
Geology	Cretaceous limestone and dolomitic strata
Lithology	Calcareous marl with clay sediments, and interlayers of sandstone
Average bathymetry	33.5 meters
Salinity	Surface: 32.6 – 38.1 ‰; Deep water: 37.5 – 38.5 ‰
Water stratification	Starts in April and stabilizes in August (Degobbis, 1988)
Water temperature	Surface: Minimum in Feb/March (10.5°C); Maximum in August (22.4°C) Bottom: Maximum in October (15°C)
Oxygen	Summer ~ 105%, Winter ~ 95%, lowest values near bottom ~ 55% (Skrivanic, 1979)
Transparency	Low and highly variable (7 – 32m), with blue-green watercolor (Smodlaka, 1987)
Tidal variation	~ 80cm
Winds	Northeast Bura (up to 1m/s) and Southeast sirocco (jugo) in winter, in summer wind Maestral
Nutrient conc.	Orthophosphate: < 0.05 mol/l; Total inorganic nitrogen: 0.0 – 2 mol/l Orthosilicate: 0.2 – 2.5 mol/l (Gilmartin et al., 1990)
Primary production	~ 22gC/l/h; chlorophyll a ~ 1.5 g/l (Degobbis et al., 1989, Smodlaka, 1983)
Lake Vrana	Surface area: 5km (5.5kmx1.5km); Volume: ~ 220 million m; Oligotrophic; Cryptodepression with depth of 74.5m, 13m above sea level; Evaporation: 1520 mm/year; (Petrik, 1957)

Table 2. **GIS - Coverage Information**

COVERAGE NAME	GEOGRAPHIC FEATURE	FEATURE CLASS	FEATURE ATTRIBUTES	DESCRIPTION
AQUA	MARICULTURE	POLY		Union coverages for environmentally suitable mariculture areas
AQUA300	BUFFERS	POLY		200m and 300m buffer zones for aquaculture
BATLINE	BATHIMETRY	LINES (AAT)	BEACH	Contour lines (- m) around the island, used for tin
BATPOINT	BATHIMETRY	POINTS	BAT	Depth (-m)
BATPOLY	BATHIMETRY	POLY	BEACH 2	Bathimetry polygons (-m), all the contour lines
BATHILL		GRID		
BATLAT		LATTICE		
BATTIN		TIN		
BEACH	BEACH AREAS	POLY		Union coverages for environmentally Suitable beach areas
BEACHBUF	BUFFER	POLY		100 meter buffer zone on both sides of shoreline cres
BENTAQUA	MARINE BENTHOS	POLY		Union of bent2 and aqua300 for suitable substrate selection
BENT2	MARINE BENTHOS	POLY	BENT	Types of marine bottom (1-6)
BIO	BENTHIC BIOCENOSIS	POLY	BIO	Types of marine biocenozis (1-5)
BIOPTS	BENTHIC BIOCENOSIS	POINTS	PTS	(1-3) sav, coral reefs, algae
BIOBUF	BENTHIC BIOCENOSIS	POLY		200m buffer zone around all points from BIOPTS
CITIESC	SETTLEMENTS	POLY	CITIES	Different size poly (1-4), resident #, 34 settlements
CITY2	SETTLEMENTS	POLY	CITY	Same size poly . no shoreline
CRES	SHORELINE	LINES (AAT)	Aquaf = 1 Aquaa = 2 Access = 1 Phys = 2	Shoreline coded for suitable aquaculture areas and beach areas Based on natural and human resources
CRES	SHORELINE	POLY		Island with shoreline
TOWNS	SETTLEMENTS	POLY	CITIES TOUR	Resident # Bed # (different size poly, no shore)
CITYBUF	SETTLEMENTS	POLY	CINSIDE	Buffer zone 2 km
CULT2		POLY		Marine protected areas

CROSHL	SHORELINE	AAT		Istra and islands
FISH2	FISHERIES	POLY	FISH	Fishery areas (1-8)
GEO2	GEOLOGY	POLY	GEO2	
HYDROG	HYDROLOGY	POLY	HYDRO	Permeability of rocks (1-3) and submarine springs (4)
HYPT	SUBMARINE SPRINGS	POINTS	HYDRO	Coverage with 5 submarine springs as points
HYPTBUF	SUBMARINE SPRINGS	POLY	INSIDE	100m buffer zone around submarine points from hypt coverage
ISHILL		GRID		
ISLAT		LATTICE		
ISTIN	ISLAND	TIN		
LAKE	BATHIMETRY	POLY	LAKE	Contour lines (1-6), coded poly
LAKESH	LAKE SHORELINE	POLY	LAKE	Just a lake shoreline
LAKESHBUF	BUFFER ZONE	POLY		Buffer zone (2,200 m)
LLAKE	BATHIMETRY	LINES	TOP	Bathimetry lines coded (–m)
MINPTS	MINING	POLY	PTS BUF	Same size poly around city2
PEAK	TOPOGRAPHY	POINTS		
PED	PEDOLOGY	POLY		Agricultural areas
POLYPEAK	TOPOGRAPHY	POLY	PEAK	129 same size poly peaks
RESERVE	LAND USE	POLY	RESERVE	Land protected areas (1-5)
ROADS	ROADS	LINES		Penned 3 coverages
ROADSBUF	BUFFER	POLY		Buffer zone (2,000 m)
RUR2	RURAL AREAS	POLY		Rural poly (1)
SHORELINE	SHORELINE	LINES		Land and island shoreline
SHOREPOLY	SHORELINE	POLY		Land and island shoreline
SHALLOW	BATHIMETRY	POLY		Contour lines (-10 – 0 m)
TOPLINE	TOPOGRAPHY	LINES		Topography contour lines with lake, used for tin
TOPOLYLINE	TOPOGRAPFY	POLY, LINE		Topography of the island cres
TOPBUF	BUFFER ZONE	POLY		Buffer zone (50 m)

TESTBAT	BATHIMETRY	POINTS	BAT	Bathimetry points around island, tin
TOPOTIN	TOPOGRAPHY	TIN		
TOPOGRID	TOPOGRAPHY	GRID		
TOPOHILL	TOPOGRAPHY	GRID		
TOPOLAT	TOPOGRAPHY	LATTICE		
TOURISM	SETTLEMENTS	POLY	CITY	Same size poly (6) coded for # of beds
VEG	VEGETATION	POLY, LINES	VEG	Submediterranean & Mediterranean Types of vegetation

Table 3. **Aquaculture Protocol**

PARAMETERS	GOOD	MEDIUM	POOR
BATHYMETRY (m)	≥ 30	15 - 30	< 15
TOPOGRAPHY (SLOPE, °)	≤ 30	30 - 45	> 45
WATER QUALITY (fecal coliforms, MPN/100ml)	≤ 14	14 - 88	> 88
SUBSTRATE	SAND or GRAVEL	MIXED ROCK	MUD
SUBMARINE SPRING *	EXISTING		NOT EXISTING
EXPOSURE	PARTIALLY EXPOSED	SHELTERED	EXPOSED
PHYSICAL ACCESS (BUFFER ZONE 500m)	WITHIN BUFFER ZONE		
WATER TEMP. (°C) MAX. MIN.	20 – 24 12	24 – 27 10	> 27 < 6
OXYGEN (%)	100	70 - 100	< 70
SALINITY (ppt) ‰	28 - 35	15 - 28	< 15
TROPHIC STATUS	OLIGOTROPHIC	MESOTROPHIC	EUTROPHIC
EROSION	LOW	MODERATE	HIGH
WATER DYNAMICS (CURRENTS) (m/s)	0.2 – 1.0	1 – 1.5	> 2
WAVES (m)	1	1 - 3	> 3
SPECIES SELECTION	NATIVE		
SPECIES TROPHIC ZONE SELECTION	POLYCULTURE (herbivorous)	HERBIVOROUS	CARNIVOROUS

Based on the PAP/RAC, 1996: Approaches for zoning of coastal areas with reference to Mediterranean aquaculture.

* The island runoff is associated with numerous small submarine springs: Martinscica, Valun, Bay of Cres, and Punta Kriza (UNEP, 1996, pp.453).

Table 4. **Aquaculture Protocol for the Island Pilot Project**

PARAMETERS	GOOD	MEDIUM	POOR
BATHYMETRY (m)	≥ 30	15 - 30	< 15
TOPOGRAPHY (m)	0 - 50	50 -100	> 100
SLOPE (DEGREES °)	≤ 30	30 - 45	> 45
SUBSTRATE	SAND or GRAVEL	MIXED ROCK	MUD
SUBMARINE SPRING	PRESENT		NOT PRESENT
EXPOSURE	PARTIALLY EXPOSED	SHELTERED	EXPOSED
WATER QUALITY (*)	NDA	NDA	NDA
PHYSICAL ACCESS (BUFFER ZONE 500m)	WITHIN BUFFER ZONE		

NDA = No Data Available

(*) Due to the presence of both port and marina in the Bay of Cres, and vicinity of the canned fish industry, it was assumed that the Bay of Cres is unsuitable for aquaculture activity, as well as for recreational activities.

GIS Coverages used for aquaculture spatial analysis:

1. Island's shoreline
2. Topography contour data set and elevation points set
3. Bathymetry contour data set and depth points set
4. Benthic substrate
5. Benthic Biocenozis
6. Submarine springs
7. Infrastructure: roads, settlements, ports
8. Buffer zones: 100m, 200m, 300m, and 500m

Table 5. **Ecotourism Protocol**

PARAMETERS	GOOD	MEDIUM	POOR
Beach area capacity (m^2/person)	8 -10	6 - 8	< 6
Water supply (l/day/person)	200 – 250	100 - 200	< 100
Water quality (E.coli) Drinking Swimming (*)	0 < 100	40 - 50 100 - 200	> 50 (MPN/100 ml) > 200 (MPN/100ml)
Beach area access (buffer zone 2000m)	Within buffer zone		
Energy supply	Adequate		
Sewage systems (Waste water treatment)	Present		
Nature Reserves	Present		
Cultural Heritage Preservation	Present		
Food Supply	Sufficient on site		
Sustainable Infrastructure Design	Present		
Ecostar Application & Evaluation	Present		

Table 6. **Ecotourism Protocol for the Island Pilot Project**

PARAMETERS	GOOD	MEDIUM	POOR
BATHYMETRY (m) (for beach area)	5	5 -10	> 10
TOPOGRAPHY (m) (for beach area)	0 - 50	50 -100	> 100
TOPOGRAPHY SLOPE (DEGREES °) (for beach area)	≤ 20	20 - 30	> 30
SUBSTRATE (for beach area)	SAND or GRAVEL	MIXED ROCK	MUD
BEACH AREA CAPACITY (m^2/person)	8 - 10	6 - 8	< 6
WATER QUALITY (*)	NDA	NDA	NDA
BEACH AREA ACCESS (BUFFER ZONE 2000m)	WITHIN BUFFER ZONE		

NDA = No Data Available

(*) Due to the presence of both port and marina in the Bay of Cres, and vicinity of the canned fish industry, the area is unsuitable for recreational activities.

GIS Coverages used for beach area spatial analysis:

1. Island's shoreline
2. Topography contour data set and elevation points set
3. Bathymetry contour data set and depth points set
4. Benthic substrate
5. Infrastructure: roads, settlements, ports
6. Buffer zones: 100m, 200m, 300m, and 2,000m

Table 7. **Spatial Use Conflict Matrix for the Island Pilot Project**

ACTIVITY ----------------- ACTIVITY	TOURISM (BEACH)	AQUA CULTURE	AGRI CULTURE	MINING/ QUARRY	HUNTING	PORT/ MARINA	RESERVE SITES	FISHERY	INFRA STRUC TURES	SEWAGE SYSTEM
TOURISM (BEACHE AREAS)		Y	N	Y	Y	Y	Y	N	Y	Y
AQUACULTURE			N	Y	N	Y	Y	N	Y	Y
AGRICULTURE				Y	Y	N	Y	N	Y	N
MINING/ QUARRY					N	N	Y	N	Y	N
HUNTING						N	Y	N	Y	N
PORT/MARINA							Y	N	N	N
RESERVE SITES								Y	Y	Y
FISHERIES									N	Y
INFRASTRUCTURE										N
SEWAGE SYSTEM										

Y Spatial use conflict exist
N Spatial use conflict does not exist

Table 8. **Distribution of population by settlement and island's carrying capacity based on potential beach area and water supply/demand per person**

SETTLEMENT	RESIDENTIAL	TOURISM ACCOMMODA TION (#bed)	WATER SUPPLY (l/s)	WATER DEMANDS (l/sec)	CARRYING CAPACITY Water	BEACH Access	BEACH Length (m)	BEACH Area (m^2)	CARRYING CAPACITY Beach (#people)
BELI	83	457	NDA *	1.6	NDA	–			
CRES	2, 108	5, 726	NDA	23.5	NDA	+	3,580	35,800	3,580
DRAGOZETICI	54	NDA	NDA	0.2	NDA	–			
LUBENICE	127	NDA	NDA	0.4	NDA	–			
MARTINSCICA	254	5, 077	NDA	16.0	NDA	+	2,220	22,200	2,200
ORLEC	270	310	NDA	1.7	NDA	–			
OSOR	210	2, 514	NDA	8.2	NDA	+	9,110	91,100	9,110
PUNTA KRIZA	69	2, 421	NDA	7.5	NDA	+	29,400	294,000	29,400
VALUN	63	580	NDA	1.9	NDA	–			
Σ	**3, 238**	**17,085**	**150 l/s**	**60.6 l/s**	**50,000 people**		**44,400 (m)**	**444,000 (m^2)**	**44,400 people**

(*) No Data Available

Table 9. Use Conflict Matrix for the Island Pilot Project

ACTIVITY / PARAMETER	TOURISM	AQUA CULTURE	AGRI CULTURE	MINING/ QUARRY	PORT/ MARINA	FISHERY	HUNTING	RESERVE SITES	INFRA STRUC TURE (*)	SEWAGE SYSTEM
Water quality Swimming	–	–	0	–	–	–	0	+	–	+/-
Water quality Drinking	0	0	–	–	–	0	0	+	–	+/-
Water supply Demand	–	0	–	0	+/-	0	0	0	–	+/-
Water temp.	0	0	0	0	0	0	0	0	0	0
Bathymetry	0	0	0	0	0	0	0	0	0	0
Topography	0	0	0	0	0	0	0	0	–	0
Pedology (soil type)	0	0	+/-	0	0	0	0	0	0	0
Benthic Substrate	0	–	–	0	–	–	0	0	–	+/-
Biocenosis (SAV)	–	–	–	0	–	–	0	+	–	+/-
Submarine Springs	0	0	0	0	0	0	0	0	0	0
Salinity	0	0	0	0	0	0	0	0	0	0
Precipitation	0	0	0	0	0	0	0	0	0	0
Beach Area (m^2)	0	–	0	–	–	0	0	0	–	+/-
Beach Access	+	–	0	–	–	0	0	0	+	0
Beach c.c. $10 m^2$/person	+/-	–	0	–	–	0	0	0	–	+/-
# tourist beds (potential # of tourists)	+	+	+	–	+	+	+	+	+	+/-
Aquaculture Access	0	+	0	0	–	0	0	–	+	0

Environmental parameters
"Anthropological parameters"

+ Positive Impact
- Negative Impact
0 Neutral Impact

(*) Considers roads, settlements, hotels, and industries.

<u>Note:</u> This use conflict matrix would differ in other areas!

APPENDIX I

The Executive Outline

1. **Objectives:**

- Define sustainable development for coastal regions
- Develop a generic framework for planning sustainable development
- Assessment of available and spatially explicit data
- Assess data limitations (indicate needed data development)
- Develop use-suitability models (protocols) based on environmental carrying capacities, and incorporate resource-based economy: agriculture, fisheries, aquaculture, and ecotourism
- Apply a generic framework to the real world (An Island/Croatian coast);

2. **Assumptions:**

- Environment sets the limits for sustainable development
- Many options exist for environmental/social development within environmental limits
- Successful management requires knowledge and understanding of "use choice" consequences (each decision narrows remaining options)
- Knowledge and awareness of consequences can be used to mitigate "bad choice" decisions;

3. **Approach:**

- Use GIS to define existing environmental conditions (in situ database, remote sensing)
- Identify environmental limitations and constraints caused by each potential use
- Identify all use options and environmental requirements for each
- Use GIS to develop "use impact" models (spatial analysis)
- Identify potential use conflicts
- Develop and evaluate several possible use scenarios in conjunction with management options (command/control, incentive/free market)

- Combine GIS database with current "use impact" models and evaluate impacts of alternative development scenarios;

4. **Project outcome:**

- A generic framework for sustainable development planning
- To create database model from which additional consideration can be added (economic, social, political)
- To establish guidelines for development of rational and integrated long-term social and economic policies for the continuing use of the coastal zone
- To establish guidelines for best available environmental assessment
- To improve environmental monitoring programs;

APPENDIX II

Protocol Methodology

Guidance for the project:

- coast, land and marine classification schemes
- literature based quality control of the scientific data
- cartographic data structures
- users activities
- selection of appropriate satellite imagery
- image unsupervised classification and interpretation
- geographic information processing and analysis

Basic strategy:

1. Establish objective: the management goal
2. Define the resources (natural and human) (environmental assessment)
3. Describe interactions between uses and resources (impact assessment)
4. Define critical issues: aquaculture an ecotourism development
5. Develop decision criteria
6. Assessment of data requirements and availability
7. Assembly and analysis of data
8. Multi criteria analysis
9. Dynamic modeling and simulation framework

Methodology elements:

- in situ field database from literature, and topographic maps
- to create a synoptic, digital database of coastal area and upland cover
- to create supporting data layers and attribute files
- to use the satellite remote sensing (Landsat Thematic Mapper) to inventory upland and coastal areas

- GIS to analyze data (suitability and spatial analysis)

Project application (three broad stages):

1. Data management
2. Evaluation and assessment techniques (environmental assessment, risk assessment, economic evaluation, and prospective studies)
3. Implementation (regulatory strategies, conflict resolution techniques)

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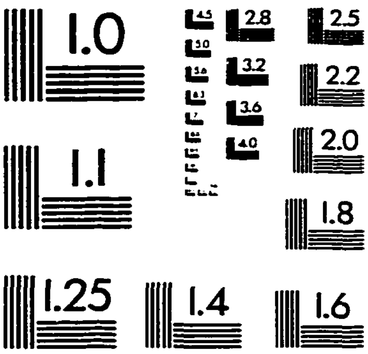
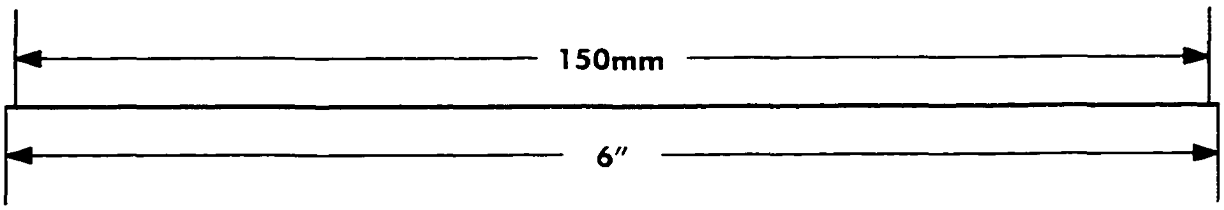
VITA

ANAMARIJA FRANKIC

Anamarija Frankic was born in Zagreb, Croatia, 30 July 1961. She earned a Bachelor of Science in Biology from the University of Mathematics and Natural Sciences, Zagreb, Croatia, in 1985. She received her Master of Science in Ecology and Limnology, at the University of Zagreb, Croatia, in 1992. She entered the doctoral program in marine science at the School of Marine Science, the College of William and Mary in 1993.

IMAGE EVALUATION TEST TARGET (QA-3)





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1653 East Main Street
Rochester, NY 14609 USA
Phone: 716/482-0300
Fax: 716/288-5989