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Integrated coastal spatial allocation and planning of aquaculture in a geographical information system approach

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INTEGRATED COASTAL SPATIAL ALLOCATION AND PLANNING OF AQUACULTURE IN A GEOGRAPHICAL INFORMATION SYSTEM APPROACH.

By

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Federal Republic of Nigeria.

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DECLARATION

I certify that all the material in this dissertation that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this dissertation reflect my own personal views, and are not necessarily endorsed by the University.

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ABSTRACT

Title of Dissertation: **Integrated coastal spatial allocation and planning of aquaculture in a Geographical Information system approach.**

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With the massive utilization of the world ´s coastal and ocean environment in terms of fisheries grounds and aquaculture, transportation, offshore exploration, tourism and ecotourism, recreation and many other serious issues like habitat loss and environmental degradation has spatial dimensions within coastal ocean space. The complexity of this highly productive environment (coastal ocean environment) characterized by multi users and uses, requires an integrated planning approach. Therefore Integrated Coastal zone managers and decision makers in developed and developing countries have to address issues of great complexity, particularly the determining the best location and allocation of maritime spaces to user and uses.

Site selection is a key factor in any aquaculture operation, affecting both success and sustainability. The correct choice of site in any aquatic farming operation is vitally important since it can greatly influence economic viability and environmental impact. It is impractical to try to control environmental parameters in planning aquaculture; Therefore, the culture of any species must be established in geographical regions that have adequate environmental and socioeconomic qualities.

In this regard, GIS is a technology that can help to clarify these issues and lead to solutions by treating many spatial and non spatial components simultaneously.

This study was intended to used GIS as a managerial decision support tool to determine and produce a suitability atlas that will be useful for developmental planning options (i.e. identifying solution spaces) for future coastal ocean space planning with a main focus on aquaculture. Although, a suitability map was not produced (for lack of required data that would generate the maps), a scenario of possible steps was described in an orderly chart representation.

KEYWORDS: Integrated coastal zone management, Geographical Information System (GIS), Food and Agriculture Organization (FAO), Coastal Ocean space and Aquaculture.

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ACRONYMS AND ABBREVIATIONS

• DFO	Department of Fisheries and Ocean, Canada.
• EEZ	Exclusive Economic Zone
• FAO	Food and Agriculture organization of the United Nation
• GESAMP	Joint Group of experts on the scientific aspects of marine Environmental protection.
• GIS	Geographical Information System
• ICAM	Integrated Coastal Area management.
• ICOM	Integrated Coastal and ocean management.
• ICZM	Integrated coastal zone management
• MCA	Multicriteria Analysis
• MPA	Marine protected Areas.
• NGOs	Non-Governmental Organization
• UN	United Nations
• UNEP	United Nations Environment programme.
• UNCLOS	United Nations convention on the law of the sea.
• UNCED	The United Nations conference on Environment and development.
• UNESCO	United Nations Educational, scientific and cultural organization.
• WMU	World Maritime University

CHAPTER 1 INTRODUCTION

´´Aquaculture development has to be advanced in a manner that is environmentally sustainable, protecting the quality of the environment for other users, while it is equally important for society to protect the quality of the environment for aquaculture. 'Environmental Codes of Practice' and National Aquaculture Plan will support this approach through the Integrated Coastal Zone Management implementation.´´
(Dr. Anamarija Frankic, June 2003)

1.1 Background

The Britannia Encyclopedia defines fish as aquatic vertebrates that are typically cold-blooded, covered with scales and equipped with two sets of paired fins and several unpaired fins. With more than 30,000 known species, fish is the largest species of vertebrates. .Fishes has an important role in many culture through ages, and scientists believe that the fish history can been dated back to 400 millions years. (O.Linden, WMU, 07)

Fish and Crustaceans have always been important resources for human being either as food, employment or for state income. This has been effectively achieved through an organized effort by humans to catch fish or other aquatic species termed Fishery. Fisheries continue to receive increasing attention not only because they represent an important source of livelihood and food as stated above, but also because of their contribution to increasing our understanding of the vast aquatic ecosystem, a strong concern not only to government, or responsible authorities but also to the civil society at large.

Population growth, urbanization and rising per-capita incomes has led the world fish consumption to more than triple over the period 1961-2001,increasing from 28 to

96.3 million tonnes. Per-capita consumption has increased over the same period and in many countries, this trend is expected to continue in the forth-coming decades (FAO Studies, 2004). In the context of stagnant production or slow growth from capture fisheries, only aquaculture expansion can meet this growing demand (FOA 2004)

Literally, aquaculture is the culture of aquatic species within, and dependent on, a synchronized environment. Aquaculture is set to become a vigorous and lucrative industry in the world over, as wild fishery continue to decline and market open for high grade farmed fish. Worldwide, this sector has grown at an average rate of 8.8% per year since 1970 as compared with only 1.2% from capture fisheries and 2.8% for terrestrial farmed meat production system over the same period (FAO, 2006 Pg.16)

The rapid growth of aquaculture world wide has stimulate considerable interest among international technical assistance organizations and national levels governmental agencies in countries where fish culture is still in its infancy and has resulted in increased concern about its sustainability in countries where the industry is well established.(S.S Nath et al, 2000).Planning activities to promote and monitor the growth of aquaculture in individual countries (or larger regions),inherently have spatial component because of the differences among the biophysical and socioeconomic characteristics' from location to location (S.S Nath et al ,2000). Biophysical characteristics may include criteria pertinent to water quality (e.g. temperature ,dissolved oxygen ,alkalinity /salinity ,turbidity and pollutant concentration)water quality (e.g. volume and seasonal profile of availability) soil type (e.g. slope ,structural suitability ,water retention capacity and chemical nature)and climate (e.g. rainfall distribution ,air temperature, wind speed and relative humidity).

Socio-economic characteristics that may be considered in aquaculture development include administrative regulations, competing resources' uses, market conditions (e.g. demand for fish products and accessibility to market) infrastructure support and availability of technical expertise. The spatial information needs for decision makers who evaluate such biophysical and socioeconomic characteristics as part of aquaculture planning efforts can be well served by geographical information systems (GIS; Kapetsky and Travaglia, 1995)

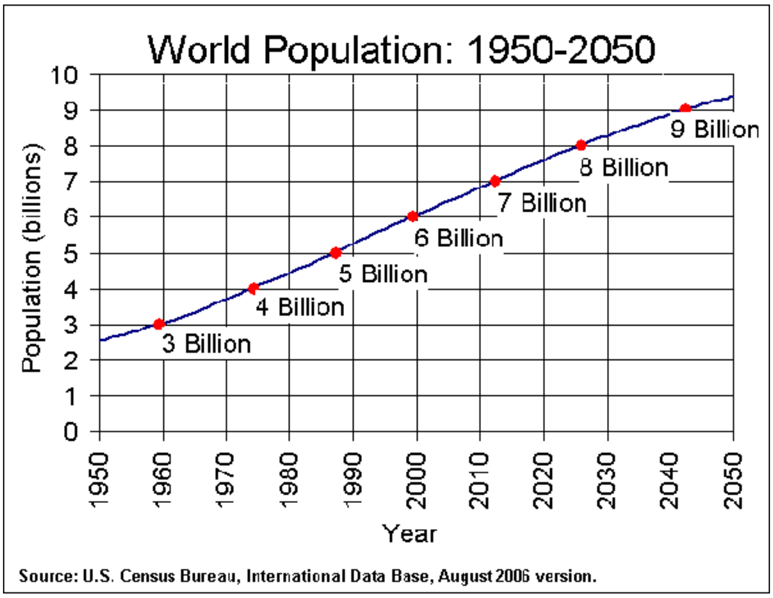
Geographical information system (GIS) technology is are computer based system, used to assemble, store, manipulate, edit, display and analyze geographically referenced data or information and its associated attributes. Today, Geographic information (GI) is vital for the functioning of modern society. It is essential for almost all decision concerning infrastructure development and spatial planning, monitoring and maintenances', trade and a large number of other socioeconomic and political matters relating to administrating to administration of territory. Therefore, the use of GIS has great potentials to optimize the value of information as a resource within an organization .The framework for spatial multicriteria decision analysis used in coastal and marine management must begin with recognition and definition of the decision problem. Subsequently, the increasing number of marine farms threatens to bring competition between fish farmer and other actual and potential users of coastal and marine space. Therefore, to ensure sustainable development of this industry ,there is great need to allocate aquacultures to suitable locations (site selection) to resolve competing demand for coastal and marine space and to avoid undesirable impact on the environment, as well as ensuring the profitability of the operation.(GESAMP 1996). Since coastal aquaculture may have significant environmental impacts, it should be addressed within an integrated coastal zone management (ICZM), scheme, and any proposed coastal or marine aquaculture plan and policy should contain an adequate allocation system.(GESAMP,1991,1996). The most suitable sites should be selected for aquaculture based on environmental, economical and social factors, in other words, selecting sites which may have the least environmental stress, maximum potentials for species growth, minimum production costs and avoiding or at least minimizing potential conflict with other users.(O.M Perez et al,2005) In general , increased deployment of GIS technology for practical decision making for selecting best suitable sites for aquaculture development has gained immersed recognition since the early 2000´s.

1.2 STATEMENT OF THE PROBLEM

Humans are altering the coastal ecosystems at an accelerating pace, hence reducing the long term capacity of these Ecosystems to provide an adequate quality of life and produce renewable wealth. Although, the pace of degradation varies greatly from location to location, region from region, and there are a few, small scale of recovery and restoration, the planetary trends are downward. Stephen B.Olsen, (1998), argued that by 2030, the costal lands are expected to contain three-quarters of a far larger human population. While the number of coastal people and the intensity of their activities spiral upward, in the vast majority of the world ´s coastal regions water quality is declining, fresh water flows to estuaries are being reduced, fish stock are collapsing and habitat critical to both people and fellow species is being destroyed. Conflicts among different competing users, groups and types of activities are becoming more intense.

The world population is projected to grow from 6 billion in 1999 to 9 billion by 2042, an increase of 50 percent that will require 43 years. (U.S. Census Bureau)Fig 1.0

Figure 1.0. World Population Forecast.



This growth is expected to have increasing demand for spatial and fish consumption. Coupled with the problems highlighted above, aquaculture is set to bridge the gap between population growth and fish consumption if properly managed and plan. Inspired with the growing threats of the world coastal regions, there is need to adopt the Bruntland Commission 1993 definition of Sustainable development for the efficient use of our coastal and marine resources and space Appendix 2.(i.e. to meet the needs of the present without compromising the ability of future generations to meet their own needs). (UNCED final report 1987) If coastal management is to become a vehicle for meeting theses future challenges, we must recognize the concept of spatial planning. The need to urgently use expert knowledge and GIS techniques for selecting most suitable sites for development of aquaculture for example along the coast of Nova Scotia in Atlantic Canada is becoming evident.

1.3 *AIM OF THE THESIS*

The aim of this study is to provide identify an approach for site selection for coastal aquaculture, using GIS analysis of existing aquaculture schemes, as well as multicriteria decision based on a wide number of environmental parameters. The resulting GIS-based approach to site selection is intended to provide planners and managers with a tool to assess land suitability for aquaculture along the Novo Scotia coast in Atlantic Canada.

1.3.1 OBJECTIVES

This objective is to prepare a detailed line of steps to be taken to achieve the above mentioned aim:

1. Examine and identify human activities in the area of study.
2. Use a digital spatial database to study the combination of the biophysical characteristics' and the socioeconomic characteristics of the study area.
3. Identify and assess the spatial content and characteristics of the existing aquaculture farms.
4. Develop and test a GIS-based multicriteria decision making approach to determine potential sites, based on a list of criteria for setting up an aquaculture farm.

1.4 *STUDY AREA*

1.4.1 Geography

Nova Scotia is known as the most famous and oldest province in Canada with its capital Halifax, located on Latitude 44^{o} 38´ North and on Longitude 63^{o}35´West .A coastline of approximately 7,400 km (4,625 miles), Surrounded by four bodies of water: the Atlantic Ocean the Bay of Fundy the Northumberland Strait the Gulf of St. Lawrence which makes it unique in the world over. It covers a total geographical area of 52,841 square km, 20,402 square miles.

Statistics Canada, as at January 2007 stated that Nova Scotia has a total population of 933,793. The average temperature in the summer is in the range of 16^0 - 24^0 C. 60^0 – 75^o F and in winter -3^o C, 20^o F.

The earliest inhabitants of Nova Scotia were the Mi'kmaq Indians. Their history tells of a magical Indian named Glooscap that could control the tides in the Bay of Fundy. The Glooscap Trail offers visions of nature at its most pristine and beautiful. The Lighthouse route is a testament to the seafaring history of Nova Scotia - visiting the town of Lunenburg is a must. Besides being home to the famous Bluenose it is also a UNESCO World Heritage site. Peggy's Cove offers a view of Nova Scotia's most famous lighthouse.

1.4.2 Culture

The character of Nova Scotia has been conditioned by the North Atlantic weather. The farmers of the Annapolis Valley and their Acadian neighbours were quite distinct from the mariners of the Atlantic coast, and different again were the diverse mixture of emigrants who came to work the coal mines and steel mills of central Nova Scotia and Cape Breton Island from the 1880s - differences that remain noticeable today.

Over 80 percent of Nova Scotia's populations trace their ancestry to the British Isles. Those with French origin rank second (18 percent). More recent immigrants to Nova Scotia have included Chinese, African, Asian and eastern European groups. 22,000 residents of Nova Scotia have Aboriginal origins and are primarily of the Mi'Kmaq Nation. The largest population groups are found in the Halifax area.

1.4.3 Industry

The resources sector started with the sea and the teeming fish of the Scotian Shelf. The catch is composed mainly of cod, haddock and Pollock, as well as lobsters, scallops and crab. Coastal and marine aquaculture is evident in Novo Scotia. The province of Nova Scotia administers aquaculture leases and licenses of 391 sites, half active while 60 are major commercial sites. Nova Scotia also has a highly developed forestry sector with four pulp and paper mills and several hundred sawmills.

The mining sector is mostly coal production. The province also mines millions of tonnes of gypsum, over 85 percent of Canada's output. Other mined resources include salt, barite, crushed stone, peat, sand and gravel. In addition to that, Nova Scotia has a large commercial agriculture sector. Dairy is the dominant sector, followed by horticultural crops, poultry, eggs, beef cattle and hogs. Export commodities include blueberries, apples and processed fruits, vegetables and juices. The province's physical location has made it well-suited for industry and trade to Europe, the Caribbean and eastern United States. Harbour facilities, modern highways, air transportation, industrial parks, research and education facilities all contribute to providing a varied and positive climate for business.

CHAPTER 2 CONCEPTUAL FRAMEWORK /LITERATURE REVIEW

2:1 Aquaculture

Aquaculture is the farming or husbandry of aquatic plants and animals ,and implicit in the activity in some degree of human intervention (A.D Boghen 2000).This working definition was adopted in 1992 by FAO .It include the farming of all aquatic resources, Fish, Molluses, Crustaceans and aquatics plants. The centre point in aquaculture is that, the property and product had to be owned and managed by an individual or group or cooperate bodies, throughout their breeding and rearing period.

Aquaculture activities are located within national jurisdictions and so governance is a national responsibility. There is a growing understanding that sustainable development of the aquaculture sector requires an enabling environment ,with appropriate institutional ,legal and management framework guided by overall policy (FAO,2006 pg 8).fish are a major sources of food protein for billions of people and their domesticated animals. The export of commercially valued species product especially Salmon and shrimps which are bred to meet the demand of the industrial countries is one main factor that has influence the rapid growth of the aquaculture industry.

Aquaculture has come under increasing scrutiny and criticism as the world tries to supply food for a population exceeding six billion. FAO ,2006 Reported that Aquaculture, the farming of aquatic organisms such as fish, molluscs, crustaceans and plants, is the fastest growing food production sector in the world[1], but its sustainability is not assured will depend on best management practice. Emphasizing, Pollution, destruction of sensitive coastal habitats, threats to aquatic biodiversity and significant socio-economic costs must be balanced against the substantial benefits which brought about the ecosystem based management practice. Aquaculture has great potential for food production and the alleviation of poverty for people living in coastal areas, particularly those people who live in developing countries. Worldwide this sector has grown at an average rate of 8.8 percent per year since 1970, compared with only 1.2 percent for capture fisheries and 2.8 percent for terrestrial farmed meat production systems over the same period (FAO, 2006 pg 16). This geometric growth should have necessariated a balance between food security and the environmental costs of production must be attained.

Thousands of years ago, humans met their nutritional needs through hunting and gathering. The demand for meat and produce has long exceeded levels sustainable by harvesting from wild populations. Agriculture became necessary to feed the ever increasing number of people. Extensive efforts in farming and raising livestock have shaped our way of life. Despite this trend, massive numbers of wild fish are still harvested from the oceans and lakes. However, the demand for fish has exceeded the available supply. Aquaculture is an obvious and needed solution to meet this shortfall

The history of aquaculture is quite uncertain probably because it may have had several beginnings that varied according to species and geography (A.D Boghen ,2002).But evidence suggest that it has be practiced in the remote/perhaps ten thousand years ago. For instance, a bas-relief discovered in an Egyptian tomb indicates that Tilapia was being cultured in ancient Egypt about 2500B.C and Japanese rearing Oysters earlier in 2000B.C (A.D Boghen, 2000).

Historians believe that in 475BC Fan Li was the first human to produce an authentic study on aquaculture focusing on the lucrative potential of spawning carp in captivity in China .His study was titled: ´´The Yang Yu Ching Treaties on Fish Breeding.

In Europe ,aquaculture started in the middle ages but by the 1850´s ,it has become well established while in North America aquaculture has proved to be a much more a recent phenomenon , and one that has been associated primarily with wild stock, enhancement for the purpose of food production (A.D Boghen,2000).The Canadian story can be traced back to the Aboriginals' people who in the earliest time ,attempts at the manipulation of stocks through the transfer of Salmon between adjacent stream and rivers. Today, methods for artificially fertilizing trout eggs are well known and stocking trout for recreational fishing continues in many countries, including Canada.

Aquaculture is indeed a business whose major commodity is food and whose driving force are profit and jobs. But opportunities for employment, income and foreign exchange from coastal aquaculture have been overshadowed by negative environmental and social effects.

2:1:1 **Aquaculture Development & Techniques**

For over 3,000 years, fish have been farmed in China, a country that continues to dominate the industry by producing 69.6 percent % of the total quantity of the world's aquaculture output and 51.2 percent of the total value of aquaculture production (FAO, 2006, Pg16). Other key producers in terms of quantities as at 2004 FAO, 2006 Report include India (6.3%), Vietnam etc a list overwhelmingly concentrated in the developing world. Everything from sea cucumbers to sea horses is farmed, but the vast majority of production is carp and other Cyprinids, accounting for over 60% of aquaculture production measured as weight or value. The remaining top cultured species include oysters, clams, cockies arkshells. Mariculture is considered a new development, but the fish farming industry is concentrated inland, with over 19.2 percent of fish produced in freshwater systems compared to 9.6 percent produced at sea.

There are a variety of production systems around the world, depending on the cultural and economic development of the region in practice. The different varieties of production techniques including ponds, tanks, raceways, and cages or "netpens".

There are hundreds of variations in technique, but there are only two significant differences (i) water processing and (ii) feeding regime. By economic necessity, most inland aquaculture facilities use a flow-through system where water is diverted from surface water (lakes, rivers) or from natural underground reservoirs (aquifers). Recycling systems only require periodic additions to top-up the water level, but the accompanying cost of filtration or aeration to maintain water quality restricts implementation. For cultured species held in natural water bodies, restrictions generally reflect site selection because water quality is heavily dependent on natural currents in and around the farm.

2:1:2 Types of Aquaculture

(i) Ponds

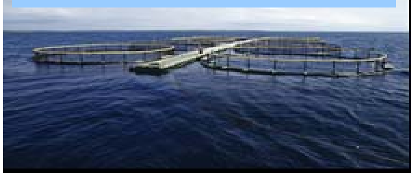
Fig.2.1 photo of Pond Aquaculture.

The early Chinese pioneers of aquaculture recognized that ponds were optimal for culturing fish. Today, the majority of freshwater aquaculture still takes place in ponds. Typically, these ponds are less than a hectare in surface area, so they are easy to manage. A pond can be natural, or it can be constructed using plastic liners. While most natural ponds are filled by runoff and rainfall, well water or surface water is often pumped into the culture pond. Pond aquaculturists use two different culturing methods. Monoculture involves raising a single species, while polyculture integrates two or more compatible fish species in the same pond.

(ii) Cages

Cage culture involves placing a mesh or wire cage in a flowing, open water system, such as a lake, stream, reservoir or ocean. Originally, cages were used by fishermen to hold their catch until the fish were ready to sell. The constant water flow is critical as it renews the oxygen supply and removes waste products with little effort by the aquaculturist. The size of mesh used for the cage is critical as it must prevent the entry of predators, while holding the valuable fish stock.

*Fig.2.2.*A typical Marine Cage site



Authors: Photos taken at West Pubnico, Nova Scotia, Canada, 2007

Cage culture is often advantageous because it can be practiced on a small scale in almost any body of water. In addition, cage culture is relatively unobtrusive to the landscape and leaves opportunity for the water to be used in other ways, such as recreational fishing. Unfortunately, the closed, confined environment may lead to the rapid spread of disease in the caged community depending upon stocking densities. Other disadvantages include the possibility of fish escaping into the environment and the cost incurred to feed the fish, as they have less access to natural food sources in the caged structure. Also, cages are vulnerable to damage by pollution, storms and vandalism.

Four different types of cages are common: fixed, floating, submersible and submerged.

(i) Fixed:

A fixed cage is essentially a net bag supported by posts which are anchored to the bottom of a river or lake. Although they are inexpensive, their use is limited to shallow, protected water with soft substrates.

(ii) Floating:

Floating cages are made from netting supported by a buoyant collar or a stable frame. This is the most widely used method of cage aquaculture because the cages can be made any size or shape.

(iii) Submersible:

These cages are built with a rigid frame and because they are submersible, they can be moved up and down in the water column to take advantage of water conditions. If the weather is rough, the cage is lowered to calmer water, but in calm conditions the cage remains near the surface.

(iv) Submerged:

These cages are the least common and are permanently kept under the water. They consist of a frame with slats for openings and are anchored to the substrate in flowing water

(v) Closed water systems

Closed water aquaculture systems are more technologically advanced than the open water pond, cage or raceway structures. Closed systems are essentially huge aquariums in which the water is filtered and re-circulated. Although they are very successful in terms of fish production, these systems require pumps, accessories and are expensive to maintain.

(vi) Raceways

Raceways are typically rectangular structures, with water entering one end and leaving through the other. The result is a constant flow rate, where fish are continually exposed to new water. In this type of system, it is possible to maintain a high density of fish in a small volume of water. Raceways are sometimes square or circular, with a large center drain. Raceways are generally open systems, with no filtration. These systems are commonly used in research facilities and in hatcheries and are made of concrete, aluminum or fiberglass.

Note; figures showing the different types of aquaculture can be found on the appendix.

2.1.3 Benefits of Aquaculture

- increase household food supply and improve nutrition.
- increase household resilience through diversification of income and food sources.
- strengthen marginal economies by increasing employment and reducing food prices.
- improve water resource and nutrient management at household or community levels.
- preserve aquatic biodiversity through re-stocking, and recovering of protected species
- reduce pressure on fishery resources if done sustainable
- improving/enhancing habitats
- stimulates research and technology development
- increase education and environmental awareness;

*2:1:*4 IMPACT OF AQUACULTURE

The rapid expansion and development of commercial aquaculture around the world has increased the number of environmental concerns and question about possible ecological, social and economic impact. Although, in the recent past the impact of aquaculture was limited due to their small scale and their low-input nature, .However, today scientific and technological development in this sector has resulted in expansion of cultivated areas, higher density of aquaculture installations and the use of feed resources produced outside the immediate area. These practices often has serious environmental impacts, concerning habitat loss (for example ,removal of mangroves),Stalinization of adjacent lands, releasing effluents into the surrounding waters, use of high quality fishmeal to produce fish and infectious diseases being spread into wild fish populations. Invasive species can also be accidentally introduced into a marine ecosystem from the escape farmed species .thereby affecting the marine and coastal ecosystem.

- ***HABITAT AND BIODIVERSITY LOSS.***

Human activities and actions such as over fishing, destructive fishing practices, pollutions with and around the coastal and marine environment has be identified as the main cause of habitat and biodiversity loss around the world. Coastal habitats are tightly interlinked , so that the loss of one habitat can have a flow on effects that degrade and reduce the services provided by linked habitat.(UNEP Synthesis, January 2006).the leading human activities that contribute to Mangrove loss are:52 percent aquaculture (38% shrimp plus 14% fish),26% forest use and 11% freshwater diversion.(UNEP Synthesis, January 2006).The case of the Philippines shows that restoration has been fully attempted ,but has not kept pace with wholesale destruction in the area. So the destruction of mangroves are particularly wasteful and costly in the long term since shrimp ponds created through Mangrove forests lose their productivity over time and tend to become fallow within 2-10 years.
Although, the added value of farmed shrimp has an economic value but the loss of sensitive habitat is difficult to reconcile with this gain.

- ***WATER QUALITY AND SALINIZATION OF ADJACENT AGRICULTURAL LANDS***

The Discharge from aquaculture facilities can be load with pollutant which degrade the surrounding environment, including excess nutrients from uneaten fish feed and fish waste ,antibiotic drugs and other chemicals including disinfectants such as chlorine and formaline ,antifouling such as tributyltin and inorganic fertilizer (UNEP Synthesis, January 2006) .The excessive use of these chemicals and drugs can also have serious health effects on humans, the ecosystem and other species.

- **Infectious disease and Alien species.**

Infected farmed fish can also escape and transmit diseases and parasites to wild stocks .In other instances, these escaped farmed fish can become invasive to the host species thereby changing the entire ecosystem structure. For example, the case of the release of tilapia in Florida has led to the loss of food, native habitat, and spawning areas for native species in Everglades National Park.

- ***SOCIO-ECONOMIC EFFECTS***

In developed countries, visual pollution created by thousands of buoys in coastal farms and the inconvenience to recreational boaters and others sharing the coastal zone, pale in significance to the socio-economic effects of aquaculture in the developing world. The quest for profit often has devastating consequences. In the Indian province of West Bengal, four fishermen were killed and over 20 injured in a dispute between fishermen and shrimp farmers as a result of access rights to Lake Chilika, one of the largest freshwater lakes in Asia.

Many nations embrace aquaculture, not as a direct way to provide food for their poor, but as a source of export wealth that can potentially lead to longer-term social benefits. Many rural communities enjoy the employment opportunities possible with aquaculture, but conflicts often develop within these communities when traditional employment clashes with the aquaculture industry. Local fishing communities often do not hold title to coastal wetlands, and have at times been displaced by shrimp consortia that have acquired leases along tropical shorelines. Resource ownership is often complex or ambiguous in prime aquaculture locations, and pollution and social concerns are often secondary to economic ones. Once touted as employment for individual operators, aquaculture is beginning to reflect terrestrial farming strategies, where small farms are absorbed into large industrial farms. An increase in culture efficiency is obtained, but employment can be reduced and the remaining small farms cannot compete economically.

2:1:5 Traditional criteria for site selection.

Traditionally, before the advent of Geographical Information System (GIS) and other decision support tools, aquaculture site selection had to go through the ´´on ground field assessment´´ and report before a site was selected .The main objective of fish producer/farmers and the decisions they make are conditioned to a large extent by the economic environment in which they operate. So like most types of development, aquaculture has emerged from a subsistence purpose to a more commercially acceptable occupation. Generally, aquaculture are planned and managed by various methodologies and criteria.

- ***Institutional Planning***

Institutional planning and analysis is an essential part of any new planning and management initiative, especially where a greater degree of integration is sought.

Institutional analysis covers both formal and informal institutions. Formal institutions are those such as government agencies that have a legal framework and procedures. Informal institutions are those such as business, social or family networks or associations.

The main types of institution which are likely to be relevant to planning and management of Aquacultures are:

- Local, district, provincial and national government (formal);
- . Agencies and advisors of government;
- . Formal and informal business associations;
- . Non-governmental organizations (NGOs);
- . Religious institutions;
- Town, village or commune decision making structures (formal and informal).

Townsley (1996) presents a summary of the institutions and levels to be considered and the specific tools which can be used to analyze them (Table 2:1). These tools are described in more detail below

Table 2.1: Institutional Issues: Rapid Rural Appraisal Tools (from Townsley, 1996)	
Community level institutions	• Venn diagrams showing membership, spheres of influence, overlaps and relative importance of different community institutions; • Decision trees for land distribution, water use and other community level decisions
Local administration	• Mapping areas of responsibility; • Venn diagrams of spheres of responsibility; • Flow charts of organizational structures; • Key informant interviews with local extension officers, local officials
Development support agencies	• Venn diagrams showing areas of activity of different development agencies, overlaps, membership; • Local peoples ranking of intervention by local agencies according to effectiveness and frequency; • Decision trees for local people regarding contacts with local institutions, requests for assistance; • Ranking of problems and priorities of different institutions and agencies; • Comparison of problem hierarchies of different agencies.
Effectiveness of aquaculture support agencies	• Local people's ranking of interventions by aquaculture extension services by effectiveness and frequency; • Decision trees for aquaculturists showing reactions to different problems: disease, input supply, etc – who they contact and why; • Comparative ranking of effectiveness of aquaculture and other support services – agriculture, forestry, fisheries, etc.

Source: Townsley.P, 1996. FAO, Technical Paper 358.

- ***Stakeholder analysis***

Stakeholder Analysis in setting criteria for aquaculture planning has put more emphasis on individual motivation and/or collective interest, than on structures and procedures.

Stakeholder analysis seeks to:

- identify, assess and compare their sets of interest;
- examine inherent conflicts and/or compatibilities, and
- describe and explore trade-offs.

(Source: Grimble and Chan, 1995; Grimble and Wellard, 1997).

Aquaculture is highly diverse with radically differing requirements in terms of site characteristics for different species.

No doubt, that water quality is generally the key. While most species grow better in high quality water and some cannot survive without it. Different species have very particular requirements in terms of both water quality and salinity. Human activities and coastal pollution must therefore be taken into consideration. At the same time, the potential impacts of aquaculture on downstream activities should be considered.

Actual site requirements are species and technology dependent, but can be divided into two main groups:

(i) those aquaculture practices that require the conversion of existing uses or natural ecosystems (e.g. conversion of agricultural land or wetland for coastal shrimp or fin-fish ponds);

(ii) those that do not require conversion (e.g. floating cages and rafts for fish or shellfish in bays and estuaries; cockles on mangrove mudflats; giant clams amongst seagrass or corals).

Brackish water ponds

The requirements for brackish water ponds are demanding, and success depends critically on site quality (SARF2003-Final Report 2006, 1994; GESAMP Report Studies 68, 2001).

Sites or areas to be avoided include the following:

- sandy soil, rocky soil, or both;
- sites with large trees;
- areas with intense acid sulphate soils and containing too high organic matter (peaty soil); and
- Areas near industrial or highly populated areas.

Marine cage culture

There is a significant literature on site selection for marine cage culture (see, for example, SARF2003-Final Report 2006; Oscar M Perez, 2005; Shree S. Nath, 2000). Critical considerations are:

- adequate shelter;
- moderate current (too strong creates problems with the set of nets, anchoring, and may be excessive for the fish; too weak and oxygen or metabolites may become limiting);
- adequate depth (to keep nets at a minimum distance from decaying organic matter and to ensure high water quality);
- Accessibility for the operators , ports and other intermodal transport for market distribution;
- minimal security (poaching) problems;
- . minimal predator problems;
- . minimal fouling;
- . suitable salinity regime (dependent upon species);
- . distance from other operators (especially where disease are potentially visible)

As noted above, more coastal and marine Geo-information still needs to be acquired and/or synthesized. Data on bathymetry, navigation channels, circulation, fisheries assessments, and many other categories of essential information are needed for planning, regulating, and monitoring and promoting aquaculture interests. In developed countries these data are readily available within the scientific community and regulatory bodies' .While in developing countries, it is quite the opposite. These and other data, when collected needed to be organized, and integrated into a GIS to improve accessibility for broader categories of coastal users.

Also a large volume of data that would have to be collected and digitized to display these species specific requirements, previous siting experience will also be incorporated and ideal locations. Lastly, sites can change, either subtly or drastically, over time as a result of natural or man made disasters an alternative sites may have to be considered.

Having considered these various literatures particularly GESAMP Aquaculture Guidelines, it is recommended that aquaculture-suitability maps be produced which identify areas where aquaculture would be constrained or prohibited using the following parameters:

1. Physical Characteristics
- temperature
- wind direction
- direction and velocity of currents
- maximum wave height/wave direction
- velocity overwash zones
- bathymetry
- surface water designations, such as outstanding resource waters (ORWs)
- Mean Low Water and Mean High Water (MLW, MHW)
- barrier beaches
- shoreline changes

2. Areas with Biological Management Designations

- endangered species and critical habitats
- identifiable nursery areas
- location of eelgrass
- plankton density
- shellfish management areas

3. Cultural Features
- access issues
- competing uses, adjacent or at location,

- Upland ownership (public vs. private)
- location of NPDES point sources (water pollution)
- navigation channels
- navigational markers with a 100' to 200' contraindication buffer

- Dredge and disposal sites

The identification and selection of suitable coastal aquaculture sites is critical not only to successful aquaculture practice, but also to the overall management of the coastal ecosystem.

2:2 GIS AS A TOOL FOR AQUACULTURE DEVELOPMENT AND MANAGEMENT.

2:2:1 History:

The term GIS first appeared in print around 1970, however the concept of it was used for troop movement planning and monitoring in every war or military action starting with the American Revolution.

French cartographer Louis-Alexandre Berthier prepared a series of maps depicting the positions of British troops at various moments in time.

Another example of early GIS use is the Cholera epidemic in 1854 in London. Dr. John Snow used the same principal as Berthier, but instead of troops, he display maps showing the deaths, and the vicinity of wells in the city water system.

GIS is a tool that integrates many other tools of investigation and, hence, one that provides both an integrating mechanism as well as new approaches to studying old problems and tackling new ones.

2:2:2. What is GIS

A GIS is any information management system which can:

- Collect, store, and retrieve information based on its spatial location
- Identify locations within a targeted environment, which meet specific criteria
- Explore relationships among data sets
- Spatially analyze the data within each environment
- Display the selected environment numerically and graphically in before and after analysis.

Theoretically, there are a number of definitions of Geographical Information system (GIS). However, by examining some of the definition, we not only have a great insight into its meaning but also appreciate its purpose. For instance, some defines see GIS as an aspect of information technology while other see it in terms of functions that it can perform. Others see it as some advanced techniques of investigation .Nevertheless, these definitions emphasize procedures that one employs and results that one expects. (See table 2.2)

Table 2.2 Defining GIS

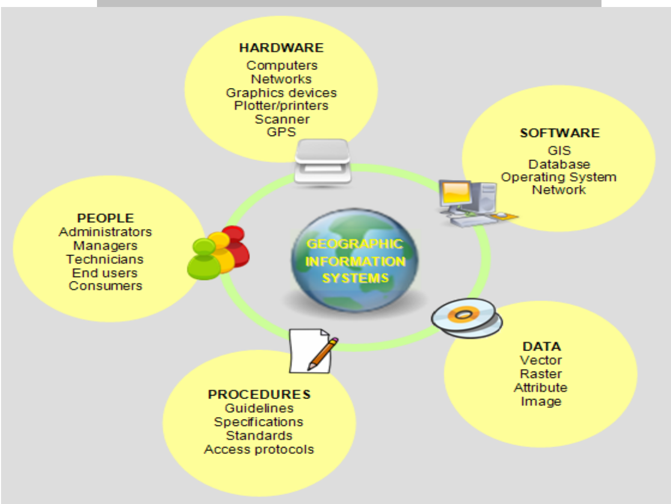
	Source	Definition
1	DoE (1987;132)	A system for capturing, storing, checking, manipulation, analyzing and displaying data which are spatially referenced to the earth.
2	Aronoff (1989);p.39	Any manual or computer based set of procedures used to store and manipulate geographically referenced data.
3	Carter (1989;p.3)	An institutional entity, reflecting an organizational structure that integrates technology with database, expertise and continuing financial support over time.
4	parker (1998;p.1547	An information technology which store analyzes and displays both spatial and non spatial data.
5	Dueker (1997:p. 106)	A special case of information system where the database consist of observations on spatially distributed features ,activities or event ,which are definable in space as points, lines or areas .A GIS manipulates data about these points, lines and areas to retrieves data for ad hoc queries and analyses.
6	Smith et al (1987 p.13	A database system in which most of the data are spatially indexed and upon which a set of procedure operated in order to answer queries about spatial entities in the database.
7	Ozemoy ,Smith and Sircherman (1981 p.92)	An automated set of functions that provides professional with advanced capabilities for storage, retrieval, manipulation and display of geographically located data.
8	Burroughs (1986;p 6)	A powerful set of tool for collecting ,storing ,retrieving at will ,transforming and displaying spatial data from the real world
9	Cowen (1988,p 1554)	A decision support system involving the integration of spatially referenced data in a problem solving environment.
10	Koshkariov, Tikunov and Trofimov (1989; p.259	A system with advanced geo-modelling capabilities.
11	Devine and Field (1986;p.18)	A form of MIS (management information system)that allows map display of the general information

- SOURCE; Maguire D.J, Goodchild M.F and Rhind D.W (1990) Geographical Information systems: Principles and applications; Volume 1, John Wiley, New York.

With this background, it is not surprising to note that GIS comprises of five main Components -:

- Users/Experts - The GIS personnel responsible for the day to day operation of the GIS hardware and software's facility.
- Hardware's - the computer system and its accessories.
- Software's - the mechanism that enhance the GIS application and operation.
- Data – Raster or Vector data format
- Procedures or Routines – the processes and end report

Fig.2.3. A Typical GIS component.



Some typical components and functions of GIS

- Input: comprises of data collection both geographically and statistical, data transfer, data verification and data Editing.
- Storage: consist of Diskettes, Disks, CD-ROM, Magnetic tape, flash disks etc.
- Manipulation: It includes cartographic functions (data conversions-from raster to vectors and vice visa, projections change embellishment) data integration, feature measurement, spatial searching and statistical analysis.
- Output: data presentation in terms of maps, graph, tables, and text data transfer etc.

The description of these components of GIS with special emphasis on the functions they perform. These include cartographic functions, data integration, features measurement and spatial search .Cartographic function include scales changes vector-raster- vector conversion, projection changed and map embellishment.

Data integration involves maps overlap, spatial aggregation and spatial transformations. Features measurement involves processes of numbering features, calculating distance, areas, volume and shape indices .Spatial search on the other hand could be conducted on points ,lines and areas to determines distance, overlay and inside. Cartographic function and data integration functions are some of the comprehensive utilities that are normally expected in good GIS software's.

Table 3: Application issues in GIS.

	USES	DESCRIPTION
1	Monitoring changes	In resources (land and building ,equipment and infrastructure) and conditions (economic ,social ,demographic ,environmental)
2	Forecasting changes	In housing requirement, in school rolls, in travel pattern, in the economy and the demand for land, leisure and community services.
3	Service planning	Through identifying and forecasting changes in patterns of need for services and investments as a basis for the delivery of services and deployment of resources .this will determine both the scales of provision and its location; it will also highlight areas of social deprivation
4	Resources Management	E.g. building maintenance, refuse collection, grass cutting, route scheduling of supplies vehicles, mobile libraries, social services ambulances.
5	Transport Network Management	Including provision and maintenance of highways, public transport schedules ,school transport and street cleaning
6	Public protection and security systems	E.g. Police command and control systems, definition of police beats, location of fire hydrants, patterns of crime and incident of fire.
7	Property Development and investment	Including the preparation of development plans ,assessing land potential and preparing property registers; promoting industrial development :rural and coastal resource management
8	Education	Use of a wide range of data for teaching purposes, school redistricting ,the use of demonstration of software's packages

Source: Maguire D.J (1989) Computers in Geography.

GIS has become a major tool of investigation not limited by disciplinary frontier .the very important uses include monitoring and forecasting changes, service planning, resource management, transport network, property development .The description of possible uses is indeed one that shows how GIS may be applied to solving generic problems. The driving force is how GIS is used has been dependent on the ability of the problem solver to conceptualize his investigation in spatial terms and to evaluate resulting analysis. Of course the ability to assemble relevant spatially referenced data is a major consideration.

2:2:3 WHY GIS IN AQUACULTURE

The development of GIS in the aquaculture industry is one that has being practice for more than a decade. The development was ignited from the collapsed of the 1992 of the Canada Cod fisheries which led to a closure which has now extended beyond of fifteen years. The first notable GIS applications for aquaculture site selection was studied and conducted by Innovative Fisheries Incorporation of S^{t}.John ´s Newfoundland to evaluate the soft-shell clam resources on three sand flats near Burgeo, Newfoundland .Spatial and nonspatial attribute data ,relating to resources assessment and management issues were collected in different formats ,integrated ,analyzed and mapped using Geographical information systems (GIS).The data collected were (i) Clam biology (ii) Hydrology (iii) water quality (iv) Landuse.

Several applications of GIS in aquaculture activities include the most famous of A.Simm´s studies on soft shell clam sites assessment in the coastal areas of Newfoundland, Canada where he determined various factors such as bathymetry data, water quality, exposure, landuse and proximity to other facilities.

Upon considering Simms and other studies and their attendant results, A. Simms mentioned three advantages of using GIS as a decision making process are -

(i).GIS provides the capacity to integrates, scales, organize and manipulate coastal and Marine Geo-information from many different sources.

(ii) Data can be maintained, updated, extracted and mapped efficiently.

(iii) GIS permits quick and repeated testing of model which could be used to aid the decision making process.

In this case, the characteristics of GIS can be applied to examine issues regarding the development and management of aquaculture. Development in GIS technology has also increased its applicability in issues regarding competing uses or coastal ocean spaces management.

GIS can be used to manage and organize operations at an aquaculture sites, if properly planned, analyzed with appropriate models from the site planning stage to harvesting plans. GIS operations can identify and map the areas to cull or harvest path. These applications can be called Prescriptive because the results of the analysis can be use as rules or guidelines for harvesting.

GIS is an important tool for aquaculture industry .These system can be used to monitor, qualify and evaluate best aquaculture sites, managements concerns such as water quality, resources sustainability as well as the economic viability of a selected species resources can be assessed within a GIS environment.

Spatial and non spatial data, as the foundation of GIS, collecting appropriate data for aquaculture site assessment is required if a resource is to be managed effectively. IS applications provides insight into the quality of the physical and socioeconomic environment as well as the sustainability of resources. However, it is the aquaculture operator who ultimately makes the final decisions (A.Simm).

With the emergence of ICZM imperative ,coastal geographic information systems are increasingly integrative of scientific and socioeconomic elements, increasingly dynamic, temporal and predictive and often the tool that effectively bring the stakeholders together.(J.L Smith and Darius J.Bartlett,2001) GIS is often defined as synergy of hardware ,software ,data and the people (ESRI 1990).Clearly, the changing role of the technology is accompanied by a changing role for the people who operates coastal information systems .

Table 4, Coastal data for GIS, Examples

Domain	Data type and sources (examples)
Topography and Terrain	Beach surveys, aerial and ortho-photographs, bathymetric charts, soil maps, catchments information.
Morphological data	Side-scan sonargraphs,sediment samples, geological bore log data
Major infrastructure	Inventory of shore protection structures, roads, marinas etc
Forestry and conservation	Forest reserves, forest types, natural vegative species, conservation areas, marine reserves
Coastal fisheries	Ensing zones, pelagic and demersal fish distribution, commercial aquaculture.
Oceanography	A variety of physical, chemical and biological oceanographic data.
Environment	Point pollution sources, water quality data, industrial site location, sensitivity analyses
Socioeconomic data	Housing location, valuation data, demographic structure and census information.
Planning	Cadastral data, past and present landuse information, administration boundaries, coastal hazard zones, development pressure (urban, industrial, aquaculture, tourism and recreation, resources, mining etc) landuse capacity, environment constraints.

Source: Haag (2006) and O´Regan (1996)

The distribution and allocation of space, ultimately of parcels of land, (with or without water covering it) to alternative uses or activities, or the control of processes that turn may affect space, such as emissions (Fedra and Feoli (1993, p.3).

In line of these GIS in coastal management has the potential to handle large dataset and databases, integrate data, share data, modelling, testing and comparing scenarios for the future and in mostly improve understanding of interactions.

An important consideration for the deployment of GIS, Remote sensing and mapping is that many of the developmental and managerial issues of marine aquaculture have underlying geographic and spatial context. (FAO Technical Paper 458, 2006) In dealing with aquaculture two environment realms are evident (i) Near shore and (ii) Offshore or the open Ocean. Each realm has its own set of issues that differ mainly in relative importance (FAO Technical Paper, (458), 2006).

Bridger el al 2003 recognizes four classes of marine aquaculture sites according to degree of exposure.

- Land based facility
- Coastal environment (protected bays and fjords)
- Exposed sites
- Offshore sites

Muir (2004) contrast coastal (onshore) aquaculture with offshore aquaculture based on four criteria that include Location/hydrograph, environment, access and operation highlighted in the table below.

2:2:4 Examples of GIS Applications in Aquaculture.

Ephraim Temple from the Department of Fisheries, Oregon state University in 2005, annotated a bibiolography of GIS applications in aquaculture. For example,

- Bush S.R 2003.Using a simple GIS Model to assess development pattern of a small –scale rural aquaculture in the wider environment of southern Laotian districts.
- Giap,D.H.,Yi ,Y.,Cuong,N.X.,Luu,L.T.,Diana,J.S., and in,C.K.2003.Application of GIS and remote sensing for the assessing watershed ponds for aquaculture development in Thai Nyuyen,Vietnam
- Nath,S.S,Bolte,J.P.,Ross,L.G.,Aguilar-Manjarrez,J.2000.Applications of geographical information systems (GIS) for spatial decision support in aquaculture.Aquacultural Engineering .Selected cases are used to illustrate the extent of GIS applications in aquaculture. The table below taken from FAO Technical paper 458 shows a summary of case applications.

TABLE 5; EXAMPLES OF GIS APPLICATIONS IN AQUACULTURE

Summary of GIS applications to culture of finfishes in cages organized by main issues

Authors	Year	Main thrust or issue	Country	Species	Software	Decision support
GIS aimed at development of aquaculture						
Kapetsky, McGregor and Nanne	1987	Strategic planning for development	Costa Rica	Fishes, mussels, oysters	Earth Resources Applications Software (ELAS)	Thresholds w/o weighting, field verification
Kapetsky	1989	Strategic planning for development	Malaysia	Fishes, mussels	ERDAS (Earth Resources Data analysis System) v. 7.2	Thresholds w/o weighting, field verification
Ross, Mendoza, and Beveridge	1993	Suitability of the site and zoning	UK	Salmonids	OSU-MAP for the PC	Thresholds w/o weighting, expert verification
Servicio de Pesca y Acuicultura	2000	Suitability of the site and zoning	Spain	Fishes	Not stated	Thresholds w/o weighting
Young *et al.*	2003	Strategic planning for development	USA	Fishes	N/G	Expert opinion, thresholds and weighting
Hoagland, Kite-Powell and Lin	2003	Economics	USA	Summer flounder	N/G	N/G
Pérez, Telfer and Ross	2003a	Suitability of the site and zoning	Spain	Sea bream and sea bass	Idrisi 32, Cartalinx 1.2	Expert Opinion and MCE
Pérez, Telfer and Ross	2003b	Suitability of the site and zoning	Spain	N/A	Idrisi 32.v1.1	Expert Opinion and MCE
Geitner	2004	Suitability of the site and zoning	Denmark	Rainbow trout	ArcView 3.2, ArcView GIS 8.2, Spatial Analyst	Expert opinion, thresholds, weighting, and field verification
Guneroglu *et al.*	2005	Suitability of the site and zoning	Turkey	Rainbow trout	ArcInfo 8.0.2 and Arcview 3.2	Thresholds w/o weighting
Pérez, Telfer and Ross	2005	Suitability of the site and zoning	Spain	Sea bream and sea bass	Idrisi 32 v 1.1, ERDAS Image v 8.3.1	Expert Opinion, MCE and estimates of carrying capacity for cages
GIS for aquaculture practice and management						
Pérez *et al.*	2002	Environmental impacts of aquaculture	UK	Atlantic salmon	Idrisi 32 v. 1.1	Particulate waste distribution for Atlantic Salmon with field verification
Corner *et al.*	2006	Environmental impacts of aquaculture	UK	Atlantic salmon	Idrisi 32 plus extension	Particulate waste distribution model for Atlantic Salmon with field verification
Multisectoral planning and management including aquaculture						
Pavasovic	2004	Planning for aquaculture among other uses of land and water	Croatia	Salmonids and oysters	ArcView 3.2 with Avenue scripts	Thresholds and linear weighted modelling
Chang, Page and Hill	2005	Planning for aquaculture among other uses of land and water	Canada	Atlantic salmon	MapInfo Professional 7.0	Thresholds w/o weighting

Table 6 .Summary of GIS application to culture –CONTINUATION

Summary of GIS applications to marine shellfish culture organized according to issues

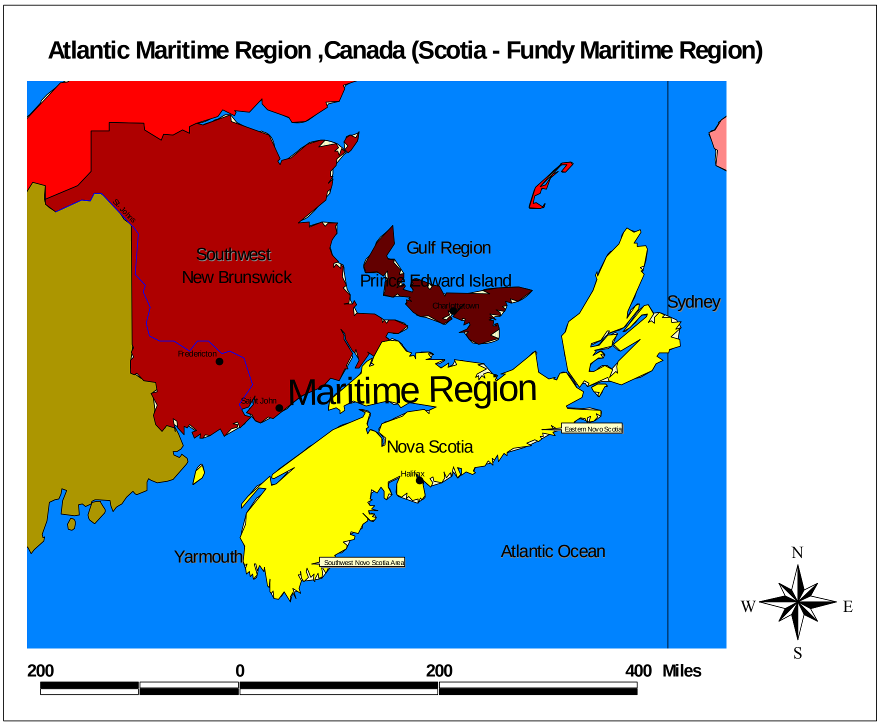
Authors	Year	Main thrust or issue	System	Country	Species	Software	Decision support
GIS for the development of aquaculture							
Scott and Ross	1998	Suitability of the site and zoning	N/G	Brazil	Mussel	IDRISI 2.0	Expert Opinion and MCE
Scott, Vianna and Mathias	2002	Suitability of the site and zoning	Long line, lantern, off-bottom	Brazil	Oyster and mussel	ArcView 3.0, SPRING 3.5,	Expert Opinion and MCE. Estimates of capacity, productivity and field verification are included
Buitrago *et al.*	2005	Strategic planning for development	Raft	Venezuela	Oyster	MapInfo 6.0	Expert Opinion and MCE
GIS for aquaculture practice and management							
Jefferson *et al.*	1991	Inventory and monitoring of aquaculture and the environment	Bottom	USA	Oyster	ARC/INFO	Mapping and characterization of oyster reefs
Legault	1992	Inventory and monitoring of aquaculture and the environment	N/G	Canada	Check	CARIS (Computer Aided Resource Information System)	Gauges pollution effects on shellfish culture. Includes and economic viewpoint
Smith and Jordan	1993	Inventory and monitoring of aquaculture and the environment	Bottom	USA	Oyster	N/G	GIS-based oyster management information system. GIS was used for management, research and education
Smith, Jordan and Greenhawk	1994	Inventory and monitoring of aquaculture and the environment	Bottom	USA	Oyster	N/G	GIS-based oyster management information system. GIS was used for management, research and education
Durand *et al.*	1994a ; 1994b	Restoration of aquaculture habitats	Bottom	France	Oyster	ARC-INFO	Thresholds w/o weights
Jordan, Greenhawk and Smith.	1995	Inventory and monitoring of aquaculture and the environment	Bottom	USA	Oyster	N/G	GIS-based oyster management information system. GIS was used for management, research and education
Smith and Greenhawk	1996	Inventory and monitoring of aquaculture and the environment	Bottom	USA	Oyster	N/G	Characterization, inventory and mapping of oyster reefs
Smith, Greenhawk and Homer	1997	Inventory and monitoring of aquaculture and the environment	Bottom	USA	Oyster	N/G	Sub-bottom profiling and side scan sonar. Used GIS to discern sedimentation over historical oyster bars and on charged oyster reefs.
Populus *et al.*	1997	Inventory and monitoring of aquaculture and the environment	Off-bottom	France	Oyster	ArcView, Spatial Analyst	GIS, by providing a capture and edition tool, a data base, script programming and mapping functions allowed to fully take advantage of the digital form of data layers and compute indicators essential to proper management of an economically important coastal resource.

2:3 Aquaculture in the study Area (Atlantic Canada)

In the 1950's, commercial aquaculture in Canada concentrated on oysters and trout. By 1995, 7% of the total fish production in Canada originated through aquaculture. Because of the collapse of many wild fisheries, aquaculture is becoming an increasingly important component of the Canadian fishery. Researchers are now working to broaden the scope of aquaculture and to develop new aquaculture species and products for the growing market. The growing aquaculture industry provides job opportunities in regions that were hard hit by the decline in the capture fisheries. Most aquaculture focuses on finfish such as Atlantic salmon, rainbow trout, brook trout and steelhead, but shellfish, especially mussels and scallops, are also important. Other fish species such as cod, Atlantic halibut, wolfish, striped bass, yellowtail flounder, winter flounder, haddock, lumpfish and eels are being investigated for future aquaculture efforts.

However, aquaculture in Canada has not grown as quickly, nor has it become as prominent as it has in other countries. Why? Harsh climates in many regions of the country limit aquaculture. The infrastructure required for aquaculture is often too costly and Canadian industry has limited knowledge and experience in the husbandry of cold water species. Also, compared to other countries, fish and marine plants play a relatively minor role in the Canadian diet as other protein food sources are available. Still, fish stocks have recently failed to meet national demand, not to mention the demand of the export market. Because of our long history on involvement in the capture fisheries, populations on Canada's Atlantic and Pacific coasts have come to depend on the fishery as a way of life, and a food source. With the collapse of many ground fish stocks more than a decade ago, aquaculture is recognized as a way to meet the demand for the popular ground fish species, without putting pressure on the already depleted wild populations

Figure 2:4 Map of the Scotia –Fundy Region.



- **ATLANTIC SPECIES**

(i) Arctic char

Arctic char are growing in popularity because of their ability to thrive at low water temperatures. They are extremely hardy fish and grow better than Atlantic salmon and rainbow trout in cold-water conditions and high densities. They are a little more difficult to farm because they show a wide variation of growth rates when placed in different culture environments. This may be due to the fish's natural ability to adapt readily to changes in environmental conditions. They are commonly used in freshwater, but marine and brackish experimental farms are currently under way.

Fresh, farmed charr are a new fish. It is considered a specialty item and gets higher prices than other commercialized salmonids such as Atlantic salmon and rainbow trout.

(ii) Atlantic cod

The crash of the Atlantic cod fishery has brought the culture of cod to the forefront of new aquaculture species. Cod are difficult to farm because of the very high rate of mortality before reaching adult size, including cannibalism among juveniles. They seem to be a good candidate for aquaculture though because they are hardy, easy to maintain and grow rapidly at low temperatures. Since the ground fishery collapse, there is still a large demand for cod, but a very limited supply

(iii) Atlantic halibut

Atlantic halibut is still considered a "new" species to aquaculture, though some cultured fish are already being sold on the Norwegian market. Halibut are a difficult culture species because of their complex early life history and complications associated with metamorphosis. It has been advantageous to overcome these obstacles because halibut have a good survival rate after metamorphosis, a high market value and a low commercial supply. Halibut make good aquaculture candidates because they are fast growers, with a high yield and only become sexually mature at a large size (so they invest most of their energy into growth, not reproduction). Halibut demand the highest price of all the ground fish.

(iv) Haddock

Haddock is another prized species of ground fish that has suffered because of over fishing. Culture research is underway, but seems promising due to a good market appeal, fast growth and a broad temperature tolerance. It has already be commercially developed but startled due to a rebuilding wild capture fishing that is reducing the market price for farmed Haddock.

(v) Lumpfish

Lumpfish are pursued commercially mainly for their roe (eggs). Research into the culture of lumpfish is ongoing because the wild populations undergo crashes every 5-7 years. The goal of the research is to enhance the stocks to prevent the closing of the fishery because of population crashes. Since the roe are usually the desired product, a culturing facility would seem to be ideal, but brood stock have a high mortality after spawning in laboratory conditions.

(vi) Salmon

Salmon have been used in aquaculture situations for over 100 years. Early in the 1900's, the federal government hatcheries began producing brook trout and Atlantic salmon for public hatcheries. The purpose of the hatcheries was to augment or re-establish wild populations, or to establish populations where none existed before. Salmon are a popular aquaculture species because they are a high-priced commodity, easily marketed, and the knowledge to breed, hatch and rear them in captivity is readily available. Their nutritional requirements are well documented, and they have been farmed for a long time. In the opinion of most consumers, cultured salmon are comparable to wild salmon, so still demand high market prices.

(vii) Striped bass

Striped bass were originally considered as an aquaculture candidate to stock freshwater lakes for sport fishermen, but recently there have been efforts to develop the retail market. The production of white and striped bass hybrids in the U.S. makes striped bass one of the few nonsalmonid species that we know enough about to develop commercial culture facilities. Striped bass are a euryhaline species, tolerating both freshwater and saltwater.

(viii) Wolfish

Wolfish are gaining popularity because they have white flesh (which is more popular with consumers), grow well in cold water and are well-adapted to the conditions in Atlantic Canada. Major problems with culturing wolfish are that they may use internal fertilization and the eggs undergo a long incubation period. They are good candidates for aquaculture because they grow well at low temperatures; they feed well after hatching, and grow large rapidly without reaching sexual maturity

(xi) Winter flounder

There has been a lot of progress made rearing winter flounder. Winter flounder share many traits with yellowtail flounder and seem to show promise as a candidate for aquaculture.

(x) Yellowtail flounder

Yellowtail flounder were a popular commercial species until the crash of the fishery. It is believed to have a good market potential, readily eats artificial food and can use the same facilities as halibut (making better use of the facilities).

Table 7 FRAMEWORK OF AQUACULTURE IN NOVO SCOTIA

Responsibilities/Administer Aquaculture	Department of Fisheries and Ocean(DFO)	Canadian environmental assessment	Province	
Sites	391	196 active	60 major commercial	
Licenses sold annually	N/A			
Aquaculture growth	$40m			
Production(KGS)	$9,134,117			
Value $	$44,013,021			
% of Total Value	100%			

Sources: Fisheries and Aquaculture-Novo Scotia (Production Statistics 2005)

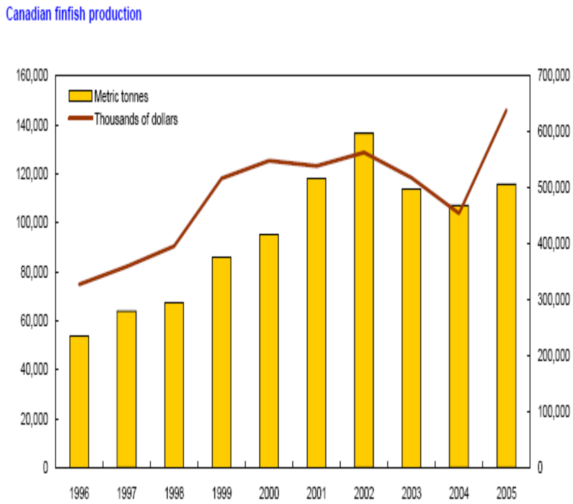
2.3.1 CURRENT THREAD AND FUTURE

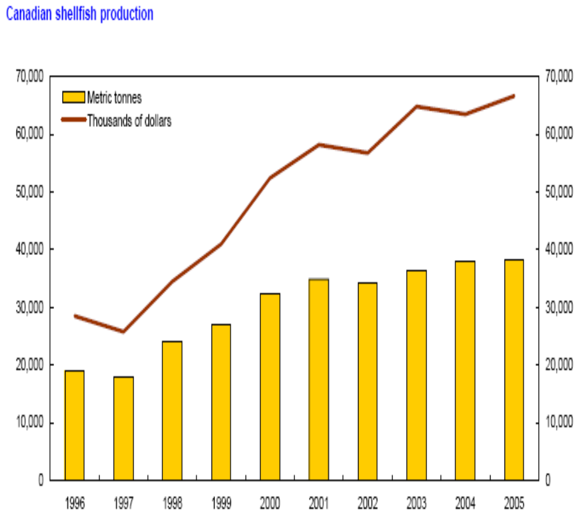
Canada has the potential to be a world aquaculture leader. Aquaculture is a new economy industry, grounded in science and technological innovation. It is a high value sector. The challenge for the Canadian industry is to create the conditions necessary to take advantage of the socio-economic potential while ensuring that the industry remains environmentally sustainable.

The industry is dominated by the production of finfish, primarily salmon off the coasts of British Columbia and New Brunswick. Production of shellfish is smaller with Prince Edward Island and British Columbia being the major producing provinces. (Canada Aquaculture statistics, 2005)

Many of these wild resources are in need of rebuilding following years of excessive harvesting and the degradation of their environments from both natural and human-induced causes which led to Cod collapse in 19 and closure for years. The industry reported record revenues of $752.6 million, up 11.0% from 2004. This increase ended in two consecutive years of declines. The aquaculture industry produced a gross output, including sales, subsidies and inventory change of $784.6 million in 2005, up 6.7% from a year earlier. In 2004, Canada’s fish farmers produced 145,840 tonnes of finfish and shellfish, more than twice the level of almost 57,000 tonnes in 1994. But total production in 2004 still represented only about 15% of the 993,054 tonnes harvested by the traditional fishery. (Canada Aquaculture statistics, 2005)

Fig 2.5. Canada Aquaculture Production pattern.





Aquaculture production has grown sometimes as much as more than 25% in a year. In terms of value, aquaculture products were worth just over $526.5 million in 2004, down 10.9% from 2003 but more than double the level of $277.6 million a decade earlier. The decline was due to a sharp drop in production and exports. (Canada Aquaculture statistics, 2005)

In 2004, aquaculture represented only 24% of the value derived from the fishery, but it was growing at a faster pace. In 1994, for instance, aquaculture accounted for less than 18% of the value of the fishery. (Canada Aquaculture statistics, 2005)

Commercial aquaculture activities produced 9000 tonnes of seafood worth $45 Million Canadian Dollars in 2005 alone. It is, therefore, vitally important that science-based measures are implemented to allocate space, protect, restore, and manage these valuable marine resources and coastal environment. Fisheries are practiced in a variety of environments including rivers, reservoirs/lakes, swamps, flood plains, deltas, irrigation canals, ponds, and rice fields. Fisheries are increasingly threatened

by environmental degradation. Human activities associated with residential and Industrial development, mining, deforestation, hydropower, navigation and agricultural land use all has had substantial negative impacts.

Other typical threats are loss of critical habitats for aquatic resources, blocked migration routes, Degradation of water quality (e.g. sewage and agricultural pollution), changes in hydrology (e.g. dams and water intake for irrigation), overexploitation, and introduction of alien species.

Canada has evolved into a dynamic component of the world aquaculture industry. Aquaculture production in Canada grew rapidly between 1993 and 2002: the 10-year growth for this period was 236% (Production in tonnes in 1993 was 53,927 and in 2002 it was 171,028). However, after 2002, the upper trend line changed and the industry has seen a reduction in production. Production decreased by 9% between 2002 and 2003. (2002: 171,028mt; 2003: 154,725mt) and underwent a further 6% decline between 2003 and 2004. See Table 7 below for detailed production data for 1999 – 2004. The declines were a result of the convergence of significant production increases by competitors, which has resulted in lower prices in the market against the development and implementation of policies and programming that impact the Canadian industry.
Details table of the pattern of growth of aquaculture for Nova Scotia can also be found in Appendix 1

TABLE .8: SELECTED AQUACULTURE PRODUCTION DATA BY PROVINCE 1999-2004

Species	Region	Production (tonnes) 1999	Production (tonnes) 2004	% Increase in Production 1999 - 2004	Value of production ($000) 1999	Value of production ($000) 2004	% Increase in Value 1999 – 2004
Salmon	Canada	72,890	96,774	33%	450,084	387,038	-14%
	BC	49,700	61,774	24%	290,600	212,038	-27%
	NB	22,000	35,000	59%	150,000	175,000	16%
Trout	Canada	6,574	4,871	-26%	32,076	22,086	31%
	Nfld	10	N/A[2]	100%	80	X[3]	-
	NB	550	400	-27%	6,100	4,000	-34%
	Que	1,185	333	-72%	6,121	1,831	-70%
	Ont	3,850	4,000	4%	15,500	15,500	0%
	Man	4	10	2%	16	41	156%
	Sask	875	-	-100%	3,859	-	-
	BC	100	128	28%	400	714	79%
Steelhead	Canada	6,002	N/A[2]	-	28,754	N/A[2]	-
	Nfld	2,078	N/A[2]	-	11,402	N/A[2]	-
	NS	3,924	N/A[2]	-	17,352	N/A[2]	-
Shellfish	Canada	27,078	37,925	40%	40,998	63,509	55%
Oysters	Canada	8,785	12,645	44%	13,278	16,207	22%
	Atlantic[3]	3,485	5,083	46%			
	PEI	2,423	3,335	38%	5,075	6,670	31%
	NS	776	314	-60%	1,815	898	-51%
	NB	286	1,434	401%	788	1,505	91%
	BC	5,300	7,562	43%	5,600	7,134	27%
Mussels	Canada	17,397	22,857	31%	23,185	32,761	41%
	Atlantic[4]	17,200	22,409	30%			
	Nfld	1,700	2,300	35%	3,800	5,055	33%
	PEI	13,890	17,576	27%	16,845	23,249	38%
	NS	945	2,083	120%	1,485	3,198	115%
	NB	665	450	-32%	798	500	-37%
	Que	197	370	88%	257	481	87%

[1]Source: Statistics Canada
[1]not available for 2004
[2]suppressed to meet the confidentiality requirements of the Statistics Act
[3]Atlantic Region: PEI, NS, NB
[4]Atlantic Region: PEI, NS, NB, NL

- **POTENTIAL OF CANADIAN AQUACULTURE**

According to the OCAD 'Achieving the Vision' report, the growth of Canadian aquaculture production will likely accelerate to 15% per year with a resultant production of 577,000 tonnes valued at $2.8 billion by 2010-2015. The projection of a 15% growth rate is based upon predicted market trends, productivity increases, and the estimates of capable aquatic resources.

A total of 73 cold-water species - including 51 species of finfish, 18 species of marine shellfish, 2 amphibian species and 2 marine plant species, are cultured commercially or are being developed for their potential as aquaculture species. Canadian aquaculture production is dominated by five main categories by volume: salmon 66.7%; mussels 15.8 %; oysters 8.7 %; trout 3.4 %.(Aquaculture Statistics 2004, Statistics Canada).

According to the Department of Fisheries and Oceans (DFO), Canada today ranks only 22nd in the world as an aquaculture producer (4th in salmon). However, it has the potential to be among the top five producers provided that public policy efforts are completed and work is undertaken to better understand and develop Canada's market potential.

- Within the next 15 years, it is projected that - at a growth rate of 10 to 15 % annually - Canada's aquaculture output could reach $2.8 billion annually in farm-gate revenues.
- Value-added processing and revenues from related supplies and services could push the total beyond $6.6 billion.
- Aquaculture promises to provide sustainable, year-round employment for more than
  47,000 people living in coastal, rural and Aboriginal communities.
- Such growth will help many communities and families prosper. For example, within ten years, cod grown on the East Coast could have a total value of $545 million.
- The Canadian aquaculture industry has developed extensive expertise in many areas. The industry now has the opportunity to export this expertise (in the form of equipment, knowledge and services) to the global market.
- Growing aquaculture output will have an increasingly positive effect on Canada's balance of trade.

The author acknowledge that this report was adopted from the Canada Aquaculture statistics.Catologue No 23 – 222XIE

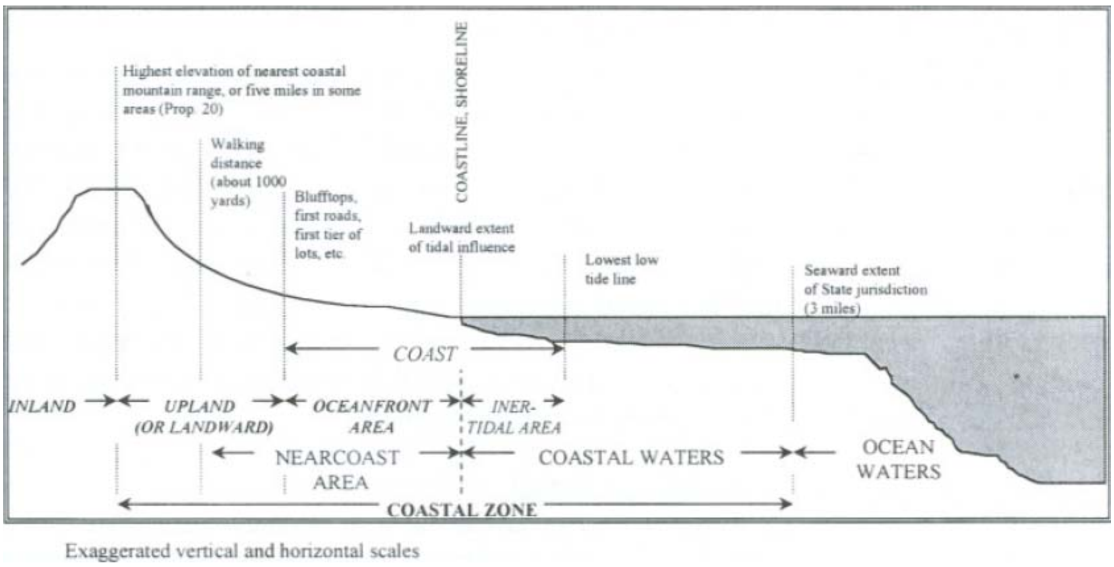
2:4 AQUACULTURE AND INTEGRATED COASTAL MANAGEMENT.

The concept of Coastal areas according to United Nations Environmental Programme (UNEP) is a notion which is geographically broader than coastal zone. This notion indicates that there is national and sub-national recognition that a distinct transitional environment exists between the ocean and terrestrial domain .This notion is of extreme importance for Integrated Coastal Area Management .Many processes ,be environmental, demographic ,economic or social ,actually takes place within the boundaries of the coastal areas ,with their extreme manifestations being most visible in the areas of the coastal zone.

Scura ,Chua ,Pido and Paw (1992:16-7) speak of coastal areas and define them as those areas that geographically form the interface between land and sea, the complex ,physical and biological processes played out there testifying to the close terrestrial and aquatic links. Ecologically, coastal areas contain a number of critical terrestrial and aquatic habitats, which comprise unique coastal ecosystems, containing a valuable assortment of natural resources.

A graphical presentation of the element of coastal zone and the coastal area is given in the figure below in accordance to UNEP (1995, 52) taken from Adalberto Vallega 1999.

Figure 2:5. A graphical presentation of the element of coastal zones.



Source: Adalberto Vallega, 1999, P19

Integrated Coastal and Ocean Management (ICOM) on the other hand tend to integrate coastal and ocean use and users and their decisions in a continues and dynamic ´´process ´´to achieve sustainable development of these areas.

Sicin-Sain and Knecht argue that decision that resources depletion, ecosystem damage and increase pollution threats are often the most significant triggers for ICOM. In light of these, ICOM major functions are

(i) To enhance area planning

(ii) .To promote Economic development

(iii).Stewardship of resources.

(iv).Conflict Resolution

(v). Protection of Public safety (and Health.

(vi).Proprietorship of public (submerged) Lands and waters.

2:4:1 ICOM INFLENENCE ON AQUACULTURE.

The goal of sustainable development is to meet the present without compromising the ability of future generation to meet their own needs. There is never an end state of sustainable development, since the equilibrium between development and environmental protection must constantly be readjusted.´´ WCED of 1987 ´´

ICOM is a process that promote sustainable development in the coastal ocean space utilization with basic integrated management tools and methodologies which include

- Scientific environmental survey and resources survey (profile report).
- Environmental Impact Assessment
- Coastal mapping and GIS systems
- Remote sensing and Benthic Assessment
- Cost Benefit Analysis and risk management Assessments.
- Habitat Assessment Reports.

It is clear that for marine aquaculture to succeed in the long term, it must be fully integrated with the collective efforts to implement ecosystem-based management and included in the broader Integrated Coastal Management framework. Therefore, strategies for management of existing operations and new development must embrace not only the social and economic goals associated with seafood production, but also be consistent with broader goals to restore and sustain the health, productivity, biological diversity of the oceans and most largely the coastal ocean space utilization.

Table 8

Characteristics of coastal and offshore aquaculture

Characteristics	Coastal (inshore)	Offshore aquaculture
Location/hydrography	05-3km, 10-50m depth; within sight, usually at least semi-sheltered	2+ km, generally within continental shelf zones, possibly open-ocean
Environment	Hs <= 3-4m, usually <= 1m; short period winds, localized coastal currents, possibly strong tidal streams	Hs 5m or more, regularly 2-3m, oceanic swells, variable wind periods, possibly less localized current effect
Access	>= 95% accessible on at least once daily basis, landing usually possible	usually > 80% accessible, landing may be possible, periodic, e.g. every 3-10days
Operation	regular, manual involvement, feeding, monitoring, etc	remote operations, automated feeding, distance monitoring, system function

Terminology: Hs = significant wave height - a standard oceanographic term, approximately equal to the average of the highest one-third of the waves.

Source: Muir (2004)

The most important consideration are reducing the impacts of aquaculture on the near coastal environment ,the need for space to accommodate large aquaculture operations that can better realize economic of scale offshore ,lessening of competition and reducing conflicts from other uses, elimination of visual impact and improvement of water quality (FAO Technical paper 458,2006) .

Cicin-Sain et al (2001) in the course of developing a policy framework of offshore aquaculture in the United States waters found that on of the major problems in all of the nations studied involved conflicts between the siting of fish farms and other coastal users such as a maritime traffic ,capture, tourism and marine protected areas. It appeared to be important then to develop a set of siting criteria for aquaculture to minimize the chances of such conflicts emerging later. In several nations such as Canada, Chile and Norway has established a formal process in guidelines of determining areas suitable for aquaculture.

Although, the primary purpose of marine aquaculture is commercial food production and related purposes including fisheries enhancement, ornamental fish, aquarium supply and medicinal-biochemical production. It should be recognized that while products of aquaculture are similar to those of capture fisheries, it is a different activity and must be managed accordingly in line with integrated management plan. For aquaculture production to be consistent with the concept of ICOM Process it must be undertaken in a way that results in acceptable changes to the local environment, i.e. it must be sustainable. Therefore, in order to be consistent with this paradigm, long-term sustainability should form the fundamental basis for developing guiding principles for planning and management of marine aquaculture.

2:4:2 GUIDING PRINCIPLES

Sustainable marine aquaculture requires adequate consideration of the interactions among the social, economic and ecological changes that accompany development. This can be achieved through an integrated approach to planning and management of marine aquaculture within the coastal system. Guiding principles that will help move toward the goal of sustainability include:

- **Legitimacy**

1. Acknowledge that marine aquaculture has the potential to produce high quality food and other marine products, contribute to social and economic well-being, and that it has a legitimate role in the broader framework of Integrated Coastal Management.

- **Rights and responsibilities**

2. Property rights and their duration must be explicitly defined and allow for the evolution of the mix of coastal zone uses over time in response to environmental, social and economic forces.

- **Communication**

3. Provide an opportunity for government and public review and communication of marine aquaculture activities that is culturally and socially relevant.

- **Science and technology**

4. Apply the best available and most appropriate science and technology for all aspects of aquaculture development, including planning, site selection, system design, management, monitoring and assessment.

- **Allocation of Resources**

5. Integrate and coordinate aquaculture planning, development and management within the broader framework of integrated coastal zone management plans, according to local, regional and national goals for sustainable development and in harmony with international obligations.

6. Recognize that aquaculture development must strike a balance between economic opportunity, the quality of the environment, the need to accommodate other legitimate water uses, and the interests of local people, the wider community, and where appropriate, the international community. Integrated resource management must include all levels of public governance (National, Provincial, First Nations, Regional and Urban) and all agencies in resource allocation decisions

7. Employ a risk analysis approach to evaluate development plans that have uncertain implications for the environment, the economy and society

8. Establish a management framework and social climate that combines both incentives and constraints for minimization of adverse effects.

- **Assessment**

9. Establish effective monitoring and assessment programs that demonstrate compliance with environmental standards and signal the onset of environmental change
10. Recognize that effective management may require iteration and adaptation.

11. Adhere to established standards for quality and safety of aquaculture products for consumers.

- **Socio-Economic Considerations**

12. All participants in resource allocation decisions must respect all users' interests and aspirations.

13. Recognize that market externalities are important in the evaluation of the utility of resource allocation solutions.

14. Local, regional, national and international economic forces and agreements all affect economic optimization.

15. Consideration shall be given to local, regional and national economic impact and local and regional employment and life quality issues.

Conceptual and numerical models are essential tools in managing and protecting coastal ecosystems. Models may be used in economic, social and ecosystem simulations for many purposes including aquaculture design, siting, and operation; ecosystem management and risk assessment; and integration of sustainable mariculture into restoration and management of coastal ecosystems.

Economic planning and decision making for mariculture

- Identifying opportunities to integrate mariculture into solving coastal problems
- Technical planning and management of mariculture operations
- Siting mariculture facilities
- Governmental permitting of mariculture operations
- Identifying gaps in knowledge
- Optimizing mariculture operations
- Characterizing and quantifying ecological processes and pathways
- Estimating the effects of human perturbation on the ecosystem
- Educating and communicating with the public
- Hindcasting “baseline” conditions

2:4:3 **PURPOSE AND USE OF MODELS**

The purpose and use of models is highly variable and serve the aquaculture industry, government planners, scientists, as well as the general public. Below are some examples of models previously used for mariculture applications?

- **Simple One-Box Model**

Box models are one of the most common models used by coastal managers. Single box models are employed using readily available inputs such as surface areas from nautical or topographic charts and volume estimates from published literature or user-performed estimates. Mass balance models are a form of the box model that accounts for all inputs and outputs of such properties as river or seawater, dissolved oxygen, macronutrients (N and P, dissolved, particulate and organic fractions), and particulate carbon deposition. Most importantly, these simple and inexpensive models produce results quickly for coastal decision-makers and are easily understood by the public.

Mass balance nutrient models that seek to quantify inputs and losses of nutrients are among the most useful of these simple models by providing coastal managers an approximate estimate of the potential effect of nutrient addition or extraction. Depending on the result, managers may quickly approve or deny a project or decide that further modeling and/or monitoring is required.

Examples of Simple One-Box and Mass Balance Models include:

Tidal prism and salt balance models to estimate flushing rates (widely used)
Mass balance models that estimate net loss and/or uptake of a constituent by calculating differences between known inputs and removals. A Gulf of Maine example was presented in our workshop from Sowles (2001).

- **Index Models**

Index models provide a ranking of impacts relative to other water bodies, operations, or technologies. These employ one-box models or empirically-derived relationships that have been quantified through measurement, correlation and other means. Although their absolute accuracy may be questionable, these indices are useful to managers and mariculturists responsible for deciding management options including the best location among several options for a certain proposed activity or the degree of impact of existing practices including aquaculture. Some examples include:

Nitrogen loading model for Puget Sound bays (SAIC 1986)
Index of Suitable Location (ISL) and Embayment Degree Model (Abo and Yokoyama 2005).
Benthic oxygen uptake, carbon assimilation and sulfide content models
Scottish management indices (Gillibrand, 2002)

- **Multiple box models**

Multiple box models are iteration between one-box models and complex hydrodynamic models with extensive grid representation. Many examples but in our workshop the pertinent example was:

Model of Tracadie Bay, PEI. (Grant et al. in press, Dowd 2005)

- **Benthic Impact, Particle Tracing Models**

A class of models generally well advanced that predicts solids accumulation on the sea bottom and effects on the benthos. Newer benthic models may include a resuspension component to estimate re-distribution of benthic materials by water currents above a given resuspension threshold. Examples include:

DEPOMOD (Chromey et al. 2002a and 2002b)
Perez et al. (2002) benthic model

- **2 or 3-D Hydrodynamic Model linked with a Biological Model**

These are complex conceptual and computational models that have the capacity to help scientists understand ecological processes and may be useful for broad geographic regions (far field) with complex bathymetry and hydrograph. This is a rapidly developing field with much interest from our participants and others but these models have several disadvantages including the requirement for extensive and expensive database support, major computation power (will not run on PC), and require a long development time before output.

Examples of multidimensional models coupled with a biological or water quality model follow:

FVCOM (with WASP5 WQ module) – Chen et al. 1999.
Princeton Ocean Model (Several literature examples)

- **3-D simple hydrodynamic models within GIS interface**

Increasingly useful, especially in the public sector are the moderate complex scale models that use 3-D computations with simplified boundaries and a widely understood graphic user interface (GUI) that operate on personal computers. Hydrodynamic simulation is simplified to achieve the benefits of easy use by model users and managers. Because of their graphical format, these also have the distinct advantage of being an excellent teaching tool for a lay audience.

These models may require species specific physiological information on metabolic rate, ammonia excretion, ingestion and defecation as well as basic hydrodynamic data (mean and peak velocity) but dispersion coefficients may be utilized from the literature or measured by the user.

This proposal includes development of a database of Aquaculture and Ecosystem constants and variables that will be needed for model development and use.

(Finally, I wish to acknowledge that the Guiding principles enumerated above was a adopted from the Ocean Institute International workshop on Role of Aquaculture in Integrated Coastal and Ocean Management, April 2005, Hawaii, USA Report)

2:4:4 Summary

Aquaculture will continue to be one of the most viable methods to supply growing world population needs, but the challenge to maintain profitability and environmental compatibility is daunting. Growth of aquaculture was fueled initially by governments eager only for economic success, but many governments have started to implement strict regulatory guidelines addressing environmental and social issues to ensure sustainability. Canada has developed stringent guidelines to maintain the health of the environment, and Brazil, Malaysia, Sri Lanka and others have all made progress in the establishment of legal and regulatory frameworks which are starting to have a positive effect on aquaculture development.

Despite such progress, their application of GIS in aquaculture site selection is relatively slow in developing countries. All too often, governments fail to provide the needed economic, legal, and social support to ensure economic and environmental sustainability. GIS is becoming an integral to development and component of natural resources management activities in the world. Hopefully, in the future the government regulatory authorities, private sector, investors and operator will all come to appreciate the relevant and usefulness of this tool for aquaculture site selection and management .Politically, food production will remain an overriding priority, and aquaculture will continue to grow. Improve models must be developed to clearly predict whether the socio-economic benefits of aquaculture are valued against the environmental costs Therefore, assessment of location and **site suitability is** a key factor in technical, economic and environmental assessment of the aquaculture sector and individual aquaculture projects.

CHAPTER 3 METHODOLOGY

3:0 Introduction

As stated in chapter two, the Department of Fisheries and Ocean (DFO) is the lead governmental parastatal committed to the development and management of the ocean resources and coastal management both inland and offshore. The DFO integrates the ecological and the social values of both the inland and ocean resources to benefit Canadian aquaculture investors. Not only do they provide a enabling business environment for aquaculture development they also provide scientific discovery, research and development and working in partnership with provinces. This is designed to develop a proactive siting process towards an efficient ecosystem based management approach and marine ocean space utilization. Bringing increased clarity, consistency and efficiency to the aquaculture site application process is an important element of implementing DFO ´s commitment to an ´´enabling regulatory environment ´´.It is intended that the information and guidelines provided here will assist in meeting these objectives.(DFO,February 15,2002).Although, many aquaculture site applications will require an environmental assessment under the Canadian Environmental Assessment Act considering the existing wild stock in the application area, reliance on wild stock, management measures, the Aboriginals and mitigation measures to minimize/eliminate potential impacts of aquaculture on the application area.

Environment Canada is the lead federal department in promoting a variety of federal environmental policies and programs relevant to aquaculture industry.

An aspect of research that is paramount importance is the use of data .This study made extensive use of GIS as defined in chapter two. This study made extensive study of the use of GIS, thoroughly discussed by Malczewski (1999). Ideally, GIS study will consist of seven phases (1).identifying project requirement,(ii).formulating specification (iii).developing the analytical framework,(iv).locating data sources (v) organizing and manipulating data for input, (vi) analyzing data and verifying outcomes (vii) and evaluating output (S.S Nath el al) .

This study was prompted by the rapid growth of onshore and near shore marine aquaculture along with an increasing number of applications for aquaculture sites in public domain marine waters.

3:1 SOFTWARE USED AND APPLICATION

Various software's and GIS software package were been used in this study, Arcview 3.2a and ArcGIS 9.1 from Environmental systems and research institute (ESRI) and Idrisi 32 from Clark labs, Worcester MA,USA.

Data integration and manipulation were being performed in Arcview 3.2a while Idrisi will be used for satellite image processing capture from the internet (data Locator).

AutoCAD (dwg file) format was used for onscreen digitizing before exporting to ArcGIS 9.1 to convert to shape file and viewed in Arcview. The software was operated on a DELL desktop Microsoft window XP professional, Intel (R) Pentium (R), CPU 2.80GHz, 512MB .The GIS database was built upon the readily made shape file download from http.www.Datalocator.com with the permission of Bedford Institute of Oceanography, Halifax, Canada. Although, it contains a large number of details while on the other hand maintaining and integrating the data for analysis is problematic.

A cartographic model is drawn in chapter 4 showing the logical steps involved in the sample GIS analysis. The model indicates the degree at which different types GIS operations are taken and applied. A tabular summary is drawn to represent the approximate number of stages in the entire process on the study.

A decision making process begins with the recognition and definition of the decision problem. Once the decision problem is identified ,the spatial multicriteria analysis focuses on specifying and creating a comprehensive set of evaluation criteria (also known as production functions) that reflects all the concerns relevant to the decision problem.(O.M Perez et al,2005).The evaluation criteria can be of two types, factors and constraints'. A factor can be defined as a criterion, which enhances or attracts for the suitability of a specific alternative for the activity under consideration. On the other hand, a constraint is a criterion which serves to limit the alternative under consideration. (O.M Perez et al, 2005).Integration of the factors and constraints into the GIS builds up the spatial database.

3:2 Database generations.

Successful decision –making depends on the quality and quantity of information/data Available for the decision makers (O.M Perez et al, 2005) .In the case of this studies, selection of criteria was done by an extensive studies from related material and articles, case studies particularly from FAO Fisheries Technical papers 458 and annual reports, and also personal interviews opinions from experience aquaculture managers in Lower East Pubnico and West Pubnico, Nova Scotia, Canada. Likewise the Nova Scotia Fisheries and Aquaculture Division also provide relative views from aquaculture siting applications.

Although, less than one third of the required data for this study are available in Arcview shape files downloaded from data locator as reiterated earlier from the permission for the BFO, Dartmouth, Nova Scotia.GIS analysis might seen difficult to perform at this junction.

3.2.1 Data capture /Entry

In fact, the advantage gained from using GIS is the efficiency of integrating such a wide range of data and information sources into a compatible format. This method involves the manipulation and bring of data from different sources and scales to a GIS format and to identify locations of objects in the original data into a systematic way for input and storage in a GIS.

The approach was to identify areas with administrative and jurisdictional incompatibilities. Data requirement for an effective site for aquaculture that will not compromise the future but attain ecosystem approach to the management of the coastal ocean space are given below;

Table 10 Data to be considered for aquaculture site selection in the study area.

	Environmental data/Biophysical data	Other Socioeconomic data
(i)	Species types	Administrative map of the study area.
(ii)	Salinity Water quality (e.g. temperature, dissolved oxygen, alkalinity/salinity, turbidity	Facility map (e.g. sewages discharge locations, oil and gas facility, mining facility, jetties, ports and military installations etc).
(iii)	Exposure	Road / accessibility map.
(iv)	Bathymetry data (depths) of the coastal and ocean space	Boundary delimitation map.
(v)	Current	Landuse map
(vi)	Wind	Thematic maps of existing aquaculture sites, artificial reefs and fish traps
(vii)	Coastal topography (slope, geology, pedology) Pollution concentration.	Thematic map of maritime protected areas.
(viii)	Rainfall distribution	Market conditions database (Forecast)
(ix)	Ship wrecks locations	Resources map of marine species, endangered species
(x)		Submarine cables
(xi)		Tourist areas
(xii)		Archeological and historical sites and zones
(xiii)		Military use zones
(xiv)		Port Navigation Areas

Source :Author

Data sources

The data requirements listed above are not available from a single source. Technically, geographic data are traditionally sourced in two ways (i) Primary Sources and (ii) Secondary sources.

(i) Primary Sources of data can be obtained from field studies such as questionnaire application; GPS data, from existing aquaculture sites, aboriginal's e.t.c

(ii) Secondary Source of data can be obtained from published texts, published maps, annual report, internets and other processed data. Although, they are coming from different sources. It is also interesting to understand that these data can be presented in different format quite different from a GIS perspective.

Here, one issue to deal with is how to integrate the entire data requirement in to a GIS format, so that GIS modeling can be tested in different scenarios.

3:3.Environmental /Biophysical Data

The nature and pattern of the Biophysical/environmental data is to determine the potential suitability of the proposed aquaculture in relation to natural phenomenon.

Environmental conditions present constraints and opportunities in the siting of a aquaculture growing operation. Consideration of environmental conditions is important to anticipating and avoiding many of the adverse impacts that could result from establishing an aquaculture project at a particular site.

These conditions can be influenced by human activities but only on a minimal level. To capture this data in a precise manner either as primary or secondary data sources into a GIS format (Arcview shape files) will be discussed in a later chapter on data analysis.

3:4.socioeconomic data

These are data that are related and influenced by the socioeconomic activities of human on the natural environment. An understanding of other human activities in the area, weather, actions of surface waters and currents, shoreline processes, environmental quality, migratory birds and species at risk must be applied to the site selection and ultimately the assessment of an aquaculture project. Environment Canada is in possession of knowledge and information on these factors.

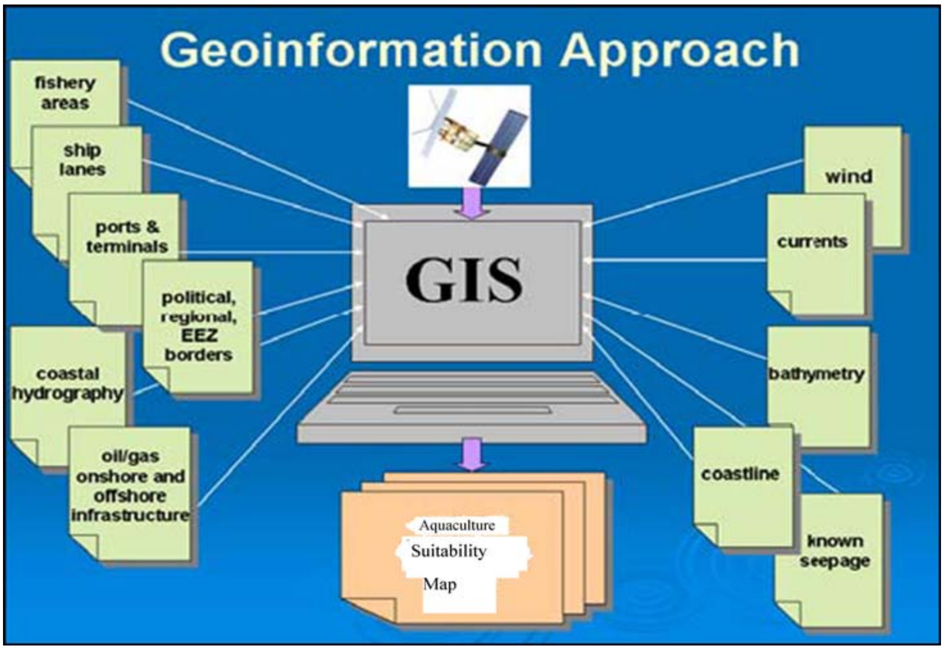
In most instances these data are captured and handled by different governmental and private agencies and stored in different formats.

3:5 Planning and management of data

Coastal zones are characterized by multi users and historical sites. So planning and management of these unique maritime spaces or ecosystems require yet another group of parameters to be considered social and environmental. (Fredrik Haag, 2006).The primary data management issues is the number of data required for this study ,the possibilities of never finding all these data in a single format, real time field data and integrating these data into a GIS storage format is just one of the challenges for a GIS analyst. The data collected on environmental and socioeconomic parameters as well as the inclusion of scanned bathymetric map provides the information required for an aquaculture site assessment. The data will be useful to determine issues on the suitability of the environment, and also to identify potential competing landuses.

Below is a graphical sample representation of marine data in to a GIS structural approach. This is aim at a better understanding of what a geoinformation approach in a GIS analysis.

Figure 3.1 GeoInformation Approach



CHAPTER 4 MULTICRITERIA GENERATION AND GIS MODELLING

4.0 Criteria generation

In order to develop and test a GIS-based multicriteria decision making approach to determine potential sites, based on a list of criteria for setting up an aquaculture farm.- Objective four. The means of conducting more complex analysis for more suitable sites for aquaculture development along the coast of Atlantic Canada is worth while investment. However, this study tends to demonstrate a modeling steps by steps GIS analysis for a suitable site selection. This was necessitated because not up to one quarter of the required data for the analysis was realized.

A Multicriteria decision approach is a collective criterion in an integrated process in realizing an achievable result. Its incorporates the Canadian Department of Fisheries and Ocean and the provincial guidelines, and structural setup, the ecosystem approach to the conservation of the marine ecosystem and other geographical studies for maximum spatial interaction. Therefore for an aquaculture farm location to yield value for its investment and on the other hand minimize or eliminate possible or potential impacts to the environment, the author has listed below multicriteria that will best produce a desirable result.

4.1 Multicriteria for this study

A statement that provides objectives, guidelines. procedures, and standards that are to be used to execute the development, design, and/or implementation portions of a project.

1. At least 1km in all directions from a First Nation's reserve (unless consent is received from the first Nation)
2. At least 1 km from the mouth of a salmonid-bearing stream determined as significant in consultation with DFO and the province.
3. At least 1 km from herring spawning areas designated as having "vital", "major" or "high" importance.
4. At least 300 m from inter-tidal shellfish beds that are exposed to water flow from a salmon farm and which have regular or traditional use by First Nations, recreational, or commercial fisheries.
5. At least 125 m from all other wild shellfish beds and commercial shellfish growing operations.
6. At least one (1) km. distance from areas of "sensitive fish habitat", as determined by DFO and the province
7. 1km, distance from the areas used extensively by marine mammals, as determined by DFO and the province.
8. At least 30 m from the entrance to an approach channel of a small craft harbor federal wharf or dock.
9. At least 1 km from ecological reserves smaller than 1000 hectares or approved proposals for ecological reserves smaller than 1000 hectares..
10. Not within a 1km line of sight from existing federal, provincial or regional parks or marine protected areas (or approved proposals for these).
11. 4km from commercial beach areas and urbanized coastal areas.
12. Not in areas that would pre-empt important Aboriginal, commercial or recreational fisheries as determined by the province in consultation with First Nations and DFO.

13. Not in areas of cultural or heritage significance as determined in the *Heritage Conservation Act*.
14. Consistent with approved local government bylaws for land use planning and zoning.
15. At least 1km from any existing finfish aquaculture site, or in accordance with a local area plan or Coastal Zone Management Plan.
16. A 500Kilometres buffer from all oil and Gas platform. (UNCLOS´82)
17. At least 50 km from international (disputed) boundary zones.
18. At least 100km from an international joint management zones.
19. 10km from military closure zones and installations.
20. 2 km from any Industrial and domestic sewage discharge point/location.
21. 1km away from sandy and pyrite soil type formation.
22. 40m from accessible routes (multimodal transport)
23. 30m from international and domestic shipping routes
24. 300m from cable network, submarine lines and pipelines.
25. Areas of the lowest annual tides. (Query)
26. Water depth in excess of 50m was excluded because moving systems becomes very complex to install and manage in deep water. (Query)

The criteria highlighted above are a reflection of the multi users and uses of the world marine environment. Various investigations have shown that Coastal regions of the world , are the most industrialized regions, so generating such detailed criteria as highlighted above is one huge task that an ICOM Manager and responsible regulatory authorities will attempt to always address across time and space.
Physical examination of the Novo Scotia coastal ocean environment has shown that it is a zone under intense pressure from all Coastal and ocean space users.

4.2 Cartographic Model:

This is a flow chart of the procedure of a GIS operation .it enables analysis and decision makers to organize and structure the step by step process of carrying out a decision support task in a diagrammatical way.

Figure 4.1: Cartographic Model

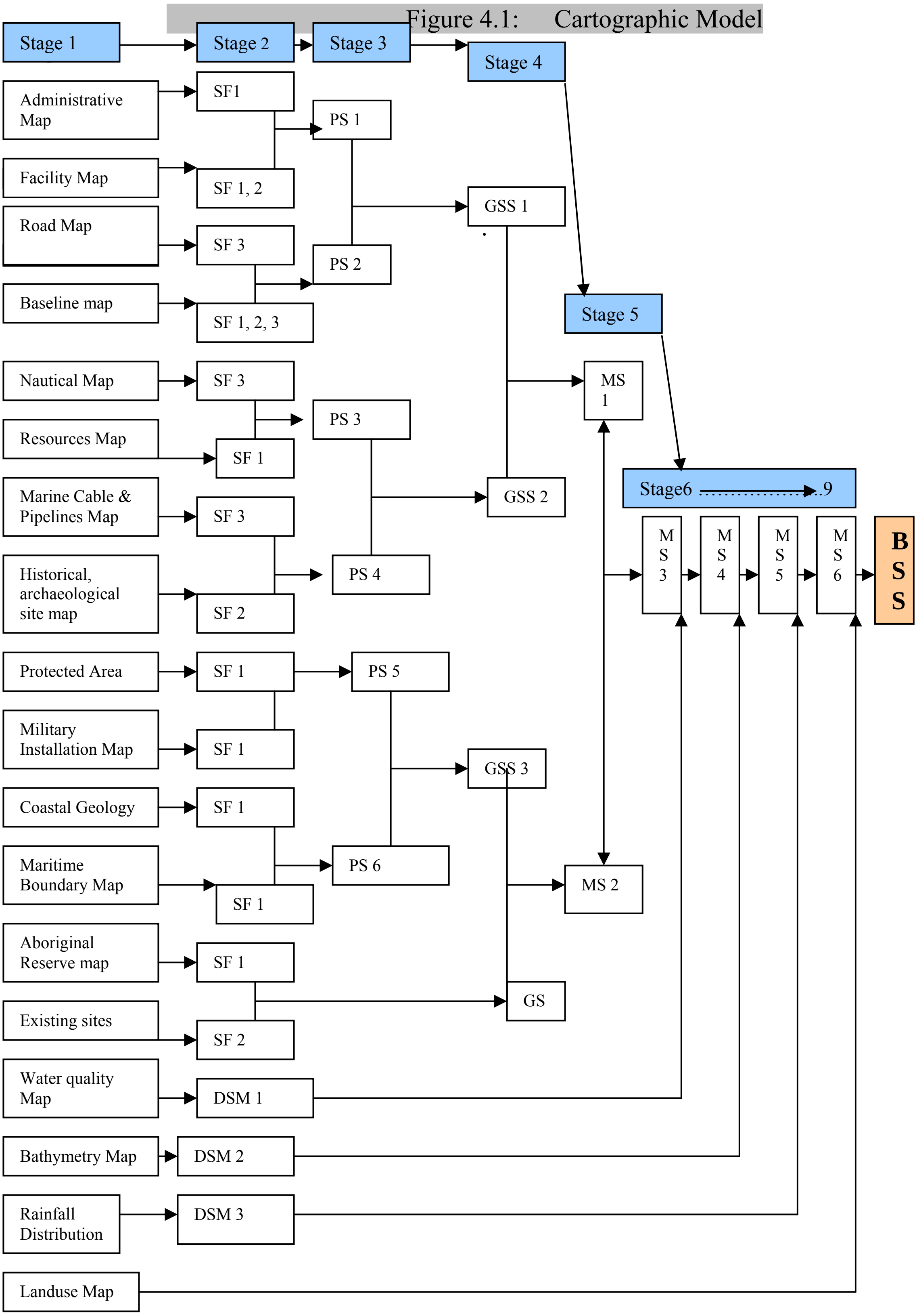


Table 11 **Table of code and features used in the cartographic model.**

Stage	GIS OPERATION	CODE	POTENTIAL MEANING
Stage 2	Polygon	SF 1	Spatial features
Stage 2	Point	SF 2	Spatial features
Stage 2	Lines	SF 3	Spatial features
Stage 2	DSM 1,	DSM 1	Digital spatial Model
Stage 2	DSM 2	DSM 2	Digital spatial Model
Stage 2	DSM 3	DSM3	Digital spatial Model
Stage 3	Overlay	PS	Potential Sites
Stage 4	Overlay /intersecting	GSS	Good sites
Stage 5 – 9	Overlay	MS	Most Suitable Sites
RESULT	Overlay	BSS	Best Suitable Sites

Source :Author

4.3 Analysis:

Analysis is the processes that are nested within one another to achieve a desirable result. GIS is a system for integrating of spatially referenced data for decision making in a problem solving environment (O.O Areola,1998).GIS is data driving and these data must be spatially referenced to enable GIS analysis to take place .The basic operation common to GIS are Buffering , Overlaying, Query operations, Intersecting operation ,Merging ,Georeferencing e.t.c.

Digital Spatial Model Generation

The generation of the digital spatial model requires the use of the INTERPOL sub-program of Idrisi for windows. The INTERPOL module uses a distance-weighted average algorithm to interpolate a full surface from point data .Access this program through ***Data Entry*** module. For the purpose of these study , DSM was perform in three geographical spaces (i)the water quality of the coastal ocean space (ii) Bathymetry map (iii) rainfall distribution .This analysis become possible because the data used were captured on points level.

4.4 Buffering

A buffer is simply creating a ring around a geographical features referring to as an area of inference of that particular future of reference.
One functionality of Arcview software’s is its capacity to design and create sequences of process in a graphical logical manner.

From the cartographic models various geographic features were buffered .Table 4:1 below shows the features that will be buffered in the analysis.

Table 12 .Spatial Features Buffered

	Geographical Features	Sources Data	GIS Format	code	Buffer operations (quantified)
1	Oil and gas platform	Facility map	Points	SF2	500m (Unclos´82) Regulation
2	National parks	Landuse map	Polygon	SF1	1km
3	Port Facility	Facility map	Point	SF2	30m
4	Sewage discharge points	Facility map	point	SF2	10km
5	International and Domestic Shipping routes	Nautical map	point	DSM	1km
6	Aboriginal Reserves	Landuse map	polygon	SF1	1km
7	salmonid-bearing stream	Marine Resources map	polygon	SF1	1km
8	herring spawning areas	Marine Resources map	Polygon	SF1	1km
9	inter-tidal shellfish beds	Marine Resources map	polygon	SF1	300m
10	wild shellfish beds	Marine Resources map	polygon	SF1	125m
11	sensitive fish habitat	Marine Resources map	polygon	SF1	1km
12	Ecological reserves	Marine Resources map	Polygon	SF1	1km
13	Existing Aquaculture sites	Existing sites map	points	SF2	1km
14	Disputed zones	Maritime boundary map	polygons	SF1	50km
15	Military installations and Zones	Military installation/facility maps	polygon	SF1	10km
16	Pipeline, cable networks and submarines lines	Submarine, Pipeline and cables lines map	lines	SF2	300m
17	Commercial Beaches	Baselines map	polygons	SF1	4km
18	Historical sites	Baseline maps	points	SF2	30

4.5 Overlay

Overlay is a Boolean operation in which is the process of combining two or more coverage's to create new sets of information, many types of overlays is possible in GIS and they involve various combinations of the three main techniques of spatial data representation .

(i) point in polygon: This is where a point coverage is combined with polygon (area) coverage as in the case of distribution of aquaculture sites in a coastal environment.(figure 4:2)

(ii) line in polygon: this is where line coverage is combined with polygon coverage as in the case of road network in a state (figure 4.3)

(iii) point in Line :this is where a point coverage is combined with a line coverage as in the case of a road network connecting harbors and ports e.t.c

(iv) Polygon in polygon: this is where polygon coverage is combine with polygon coverage as in the case of military installation zones in the study area.

Overlay operations are a unique feature of GIS software's. Their greatest utility is the ability to combine spatial and tabular information pertaining to coverage's for deriving new information and further analysis.

Methods of Overlay

Beginning from stage two ,when the data has been converted to a GIS format (digital maps),overlaying analysis will be perform to separate potential zone from used and important areas.

In this last stages of the analysis (figure 4.0) , water quality was overlayed on the MS 3 map, likewise Bathymetry on MS4 and Rainfall MS5 and MS6 features .The digital spatial model (DSM) was in Raster image whereas the MS3 and landuse layers are in vectors files. One way to be able to overlay or drape them on the DSM is to convert them to raster format. The process of overlaying landuse (vector file) to

MS5, the same principle will be applied to MS3 TO MS4 to enable overlays. This is possible to do using Idrisi´s for window Polyras, a polygon vector-to vector conversion module.

4.6 QUERY

The query is one basic operation in GIS.A spatial query is an operation that searches the database of a spatial entity for depicting its attributes. A query may also be given to search for a specific relationship between one entity and the other.Thus; most queries are of three types:

(i) Searching for specific features in a coverage using a unique identifier such as the name of a particular harbors and port in a facility map E.g. How many fishing harbors are within location A and B.

(ii) Selecting a particular feature or particular features using distinct numeric expressions. For instance, water depth in excess of 50m in deep water.

(iii) Selecting features located within diverse coverage's that meet specified spatial relationships.

4.7 DISCUSSION ON GIS APPLICATION.

Thus far, we have described the principles of geographic information systems, the nature and characteristics of geographical data and processes of analyzing spatial data into useful information for decision makers particularly in the aquaculture site suitability map .GIS is potentially useful in many areas of environmental planning and monitoring, as I have earlier stated throughout this study. The range of application is vast and is only limited to the knowledge of the user.

Consequently, The aim of describing this example in a cartographic model is both to encourage government agency responsible for coastal ocean space management and potential investors to consider this tool as a means to an end rather than deploying traditional and non environmentally friendly tools and approaches to coastal ocean space management. For instance, the geographical location of Nova Scotia within Atlantic Ocean makes it possible for that province to attain high quality fishing and coastal resources. This is a confirmation that there are possibilities of suitable sites along the coast and within it territorial waters distributed across space, but without a appropriate technical application of selecting viable sites that may be environmentally sustainable and are economically viable. These areas cannot be identified so easily within a limited time and space. This is why GIS tools add considerable value to siting process.

Considering the basic GIS Cartographic model (figure 4.1) , notified protected areas and spawning areas are given due propriety in this study as well as proposed areas for oil and gas platforms and any disputed areas are also considered in planning process.

Based on the degree of compatibility among the data considered, three zones will be identified and demarcated: (1) suitable zones (no incompatibilities), (2) zones with limitations, and (3) exclusion zones (aquaculture incompatible with already existing/ conflicting uses). The proposed result will amount to a coastal aquaculture use suitability atlas.

CHAPTER 5 CONCLUSIONS AND RECOMMENDTIONS

Environmentalists and others involved in environmental issues constantly stress the good health and sustainable use of our coastal and ocean resources as being of critical importance, given their role in food production, economic activity, genetic biodiversity and recreational activities. In addressing coastal management and aquaculture, it is essential to strike a balance between the need for economic development and the need for natural resource conservation within the same management plan (**Dr. Anamarija Frankic, June 2003).**

Therefore, integrated coastal management and sustainable aquaculture development in this study, includes careful consideration of a multiplicity of parameters and their interactions and how GIS can be used to model different scenarios and achieve a suitability site atlas.

Adequate policy should be enacted to address the resolution of potential conflicts, which is often hindered by lack of information or appropriate methodologies.

Planning for sustainable uses is a process that comprehensibly and holistically analyses marine and coastal systems, natural resources conditions, human uses and socio-economic aspects.

Fisheries management and planning has many spatial components (e.g. movements and migrations of resources, definition of fishing grounds, transportation networks, markets).Many serious issues like habitat loss and environmental degradation have spatial dimensions, therefore fisheries biologists, ICOM managers and decision makers in developing countries have to address issues of great complexity. In this regard, GIS is a technology that can help to clarify the issues and lead to solutions by treating many spatial components simultaneously. (FAO technical paper 449, 2003)

Geographic information systems are a new concept in the area of planning and monitoring of the environment, most especially in the coastal ocean space management. Nonetheless, it has become highly desirable as a result of the increasing need to achieve a sustainable development strategy .This on its own has more than ever before emphasized the role of information and the institutionalization of spatial decision support systems in the development process .Geographical information provides the framework for data collection ,the storage and analysis .Furthermore, GIS provides a consistent mechanism for the integration of data from various sources and the incorporation of elements of decision support .GIS also present a wider range of modes of media for the presentation of results than has been the case in scientific investigation and analysis.

Geographical Information System although described as consisting of a set of tools, do require more than a technician's approach to their understanding, full appreciation and use. In other words, it should not be seen as a case of plucking tools from some types of shelf. GIS is not an off-shelf type of tool-kit and should not be approached from this perspective.

I have in this study, demonstrated reveal requirement for a clear understanding of what GIS is and how it can be utilized to address some of the complex problems that ICOM managers and responsible authorities face in the day to day performance of their duties particularly coastal Ocean space planning and utilization. An important basis for sound policy decisions and plans is scientific information, in functional, planning and scientific terms coastal areas must be considered complex systems involving interactions between natural and socio-economic development components (Van der Weide 1993, dee Vrees et al, 1995)

This study focused on the selection of the most suitable sites for coastal and marine aquaculture, which is vitally important as it can greatly influence the economic viability of a venture by determining its capital outlay, running costs, rates of production and mortality factors. It can also resolve conflicts between different coastal activities and users, such as fishing or tourism, and thereby make rational and sustainable use of Atlantic Canada's coastal space. Hence, this paper integrates a GIS approach with multi-criteria analysis (MCA) for assessing the suitability of a potential aquaculture site for development. Here, MCA provides a systematic approach that can make explicit the value judgments of investors about how important each facet of environmental and socioeconomic parameters, ecological habitat (e.g. access to public harbor, ports and spawning zones e.t.c) in determining their overall preference for choosing a location in one area, compared to another.

ARCVIEW 3.2a Statistical analytics Modules can be applied in a further analysis to incorporate investor's opinions as weights into an evaluation of multiple data of assessment; it will be useful to determine the overall attractiveness of an area for aquaculture. The approach when utilized, allows ICOM managers and decision makers to examine multicriteria data requirements from both the environmental and economic perspective so that demand and supply issues can be better managed in favor of the future.

However, this study was proposed to be based on the extensive use of GIS because besides performing straightforward database functions, it can also be used to explore relationships by querying data in different ways combining relevant thematic data layers and exploring the possible relationships between them, using overlaying functions and more complex modelling structures. This allows exploration of sensitivities of the models and investigation of different scenarios, leading to optimization of site location, exploration of visual and environmental impacts and estimation of sustainable production benefits.

But this was not ***realistic*** in real terms as virtually all the required data for the GIS analysis were not reached, so a test scenario with a cartographic model was adopted as an illustration of a multicriteria analysis. These multicriteria analyses with the aid of GIS application should be practice and considered when determining the suitability of a coastal ocean site for aquaculture mainly within the exclusive economic zone (EEZ).

One major challenge for GIS analysts and managers is in the context of data acquisition, particularly in the maritime sector, where it is less well developed, except for the navigation and cartographic applications.

From an integrative management and planning perspective, it would be beneficial for national developers to establish a common agency that provides the basic information database, where data identified that are crucial (such as the data listed in Chapter 3 in this dissertation) are shared without restrictions.

As part of the constraints experience in this study, It has not addressed other aspects such as fish prices or the market economy of fish, which are as important, if not as important in affecting a investor's decision making. In addition, this study did not consider the impact of services outside the study area (coastal zones). Integrated GIS market information is also increasingly useful for developing an appropriate policy (relating to development of aquaculture and subsidies).

Further study is required to analyze how far desirability based on socioeconomic measures alone can realistically capture the pattern of demand for Farm fish, and to assess how the services outside the study area may impact on the overall suitability of the areas for aquaculture development.

However, by incorporating the locational information for the infrastructure planned to be constructed in the future, the methodology proposed in the study can be used to help planners evaluate the desirability of the potential sites for aquaculture development according to MCA.

Most ICZM conflicts evolve around the diverging interests of coastal ocean space utilization versus environmental protection census. The harmonization of these interests lies at the heart of spatial planning.

Lately, we have all failed globally, to conceive of the oceans and coasts as our largest public domain, to be managed holistically for the greater public good in perpetuity. We have only begun to recognize how vital our oceans and coasts are to our economies as well as to the cultural heritage of our nations. Therefore, an effective coastal ocean spatial planning will assist in minimizing the major conflicts between the siting of fish farms (aquaculture) and other uses of the coastal waters such as maritime traffic, capture fisheries, tourism and the protection of the natural areas. However, we have been slow in recognizing the importance of GIS in enhancing decision support for managers and investors and how easily this tool can unearth the hidden geographical content of the world coastal ocean ecosystems.

Finally, humans were not responsible for being 'awarded' with such a beautiful treasure, but we are certainly responsible and obligated to do everything in our power to preserve the natural and cultural values of our coastal ocean spaces and resources for the generations to come.

Appendix 1.Production table of Aquaculture in Nova Scotia.

Aquaculture Production, Quantity and Value, Nova Scotia, 1998–2002

	1998	1999	2000	2001	2002
			Quantity		
Aquaculture Production by Species	**(tonnes)**	**(tonnes)**	**(tonnes)**	**(tonnes)**	**(tonnes)**
Total	**4,066**	**6,477**	**10,456**	**8,067**	**4,197**
Total Finfish [1]	**2,823**	**4,715**	**8,106**	**5,600**	**2,385**
Salmon	1,785	791	3,425	2,614	1,951
Trout	--	--	--	--	--
Steelhead	1,038	3,924	4,681	2,986	434
Total Shellfish	**1,243**	**1,762**	**2,350**	**2,467**	**1,812**
Clams	--	--	--	--	--
Oysters	377	776	773	438	349
Mussels	835	945	1,252	1,619	1,073
Scallops	21	25	19	8	16
Other	10	16	306	402	374

			Value		
Aquaculture Production by Species	**($'000)**	**($'000)**	**($'000)**	**($'000)**	**($'000)**
Total	**19,437**	**27,883**	**43,476**	**29,951**	**19,935**
Total Finfish [1]	**16,635**	**24,374**	**38,288**	24,138	13,872
Salmon	10,540	7,022	18,893	14,631	12,504
Trout	--	--	--	--	--
Steelhead	6,095	17,352	19,395	9,777	1,368
Total Shellfish	**2,802**	**3,509**	**5,188**	**5,513**	**5,763**
Clams	--	--	--	--	
Oysters	1,186	1,815	1,891	1,327	1,076
Mussels	1,458	1,485	1,442	2,002	2,288
Scallops	135	166	162	88	152
Other	23	43	1,693	2,096	2,247

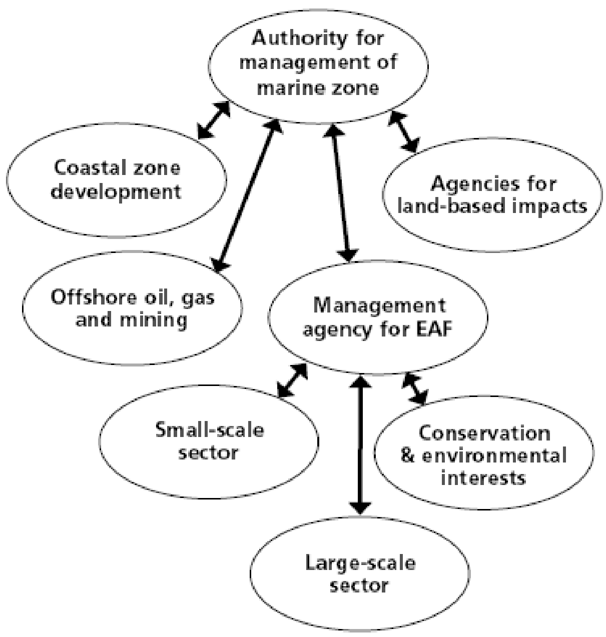
(1) Excludes "Other" (Char and other Finfish) for provinces

Note: The production and value of Aquaculture include the amount and value produced on sites and exclude hatcheries or value added products.

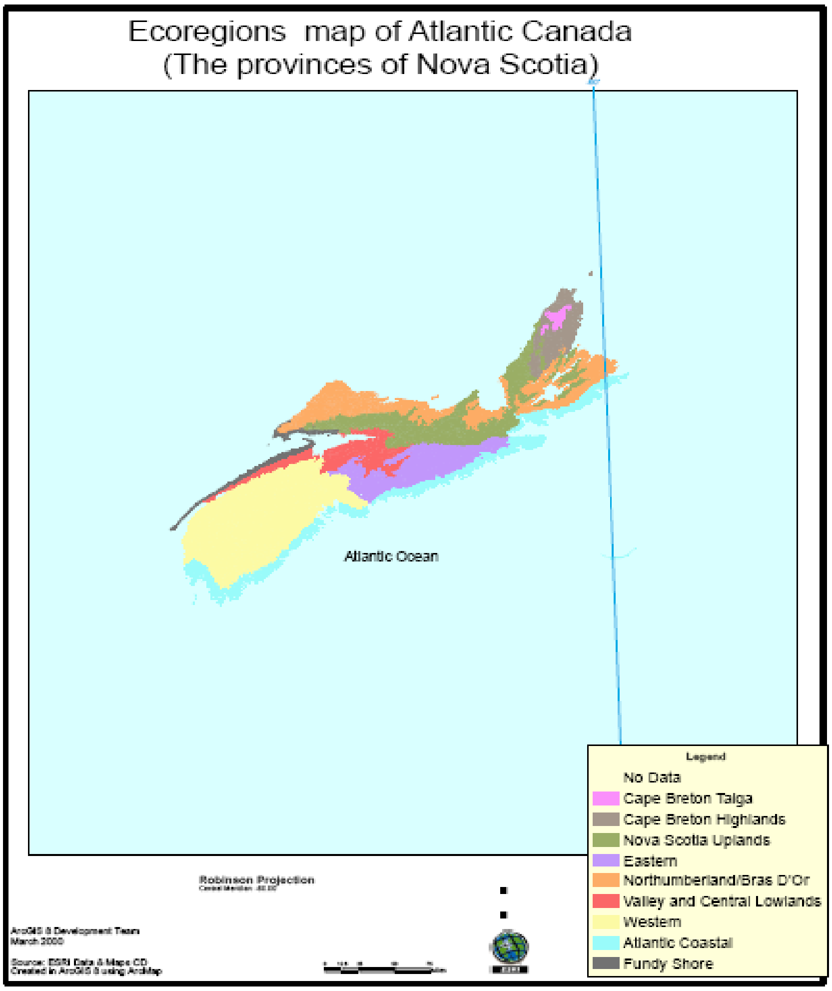
Source: Statistics Canada. Aquaculture Statistics 2002. Catalogue No. 23-222-XIE. Table 1 and CANSIM Table 003-0001

Appendix 2. Ecosystem Approach structure

An ecosystem approach to management requires coordination, consultation, cooperation and joint decision making not only between different fisheries operating in the same ecosystem or geographical area, but also between the fisheries ,management agency and the other sectors that have an impact on fisheries or are effected by fisheries. Authority for management of marine zone Agencies for land-based impacts Coastal zone development, offshore oil, gas and mining Management agency for EAF Small-scale sector Large-scale sector Conservation & environmental interests.

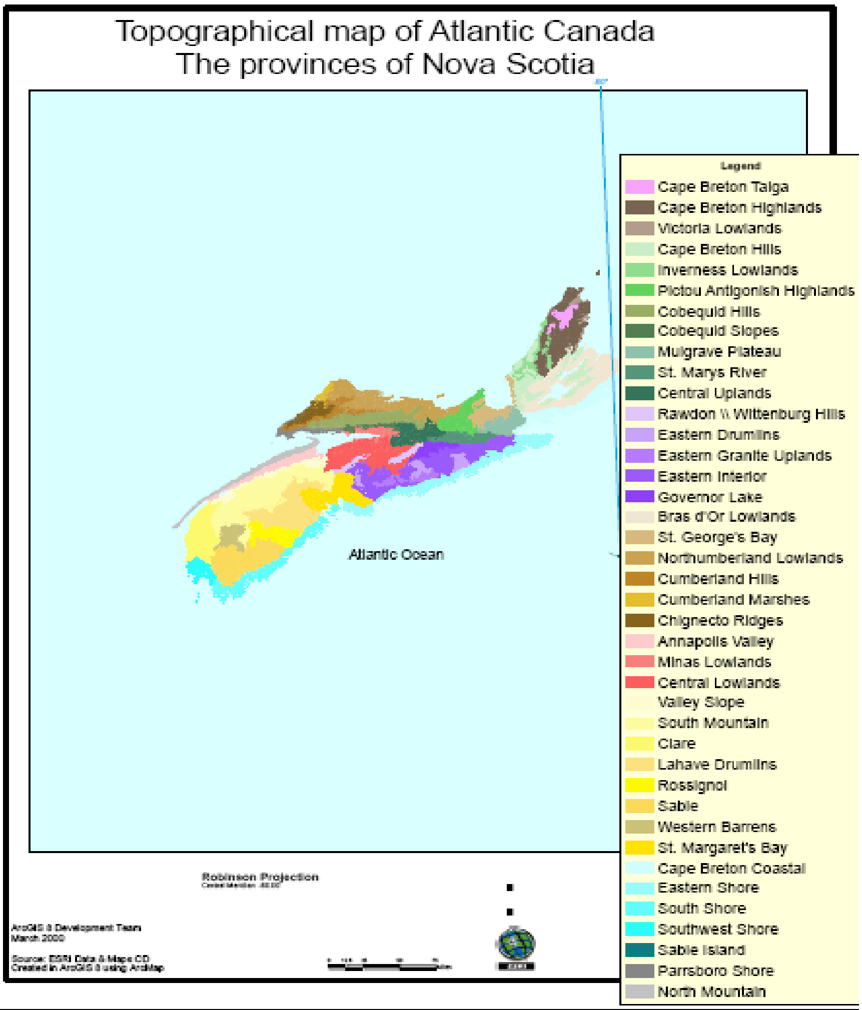


Appendix 3



Ecoregions map of Atlantic Canada
(The provinces of Nova Scotia)
Atlantic Ocean
Legend
No Data
Cape Breton Talga
Cape Breton Highlands
Nova Scotia Uplands
Eastern
Northumberland/Bras D'Or
Valley and Central Lowlands
Western
Atlantic Coastal
Fundy Shore
Robinson Projection
ArcGIS 8 Development Team
March 2000
Source: ESRI Data & Maps CD
Created in ArcGIS 8 using ArcMap

Appendix 4


Topographical map of Atlantic Canada
The provinces of Nova Scotia
Atlantic Ocean
Legend
Cape Breton Taiga
Cape Breton Highlands
Victoria Lowlands
Cape Breton Hills
Inverness Lowlands
Pictou Antigonish Highlands
Cobequid Hills
Cobequid Slopes
Mulgrave Plateau
St. Marys River
Central Uplands
Rawdon \\ Wittenburg Hills
Eastern Drumlins
Eastern Granite Uplands
Eastern Interior
Governor Lake
Bras d'Or Lowlands
St. George's Bay
Northumberland Lowlands
Cumberland Hills
Cumberland Marshes
Chignecto Ridges
Annapolis Valley
Minas Lowlands
Central Lowlands
Valley Slope
South Mountain
Clare
Lahave Drumlins
Rossignol
Sable
Western Barrens
St. Margaret's Bay
Cape Breton Coastal
Eastern Shore
South Shore
Southwest Shore
Sable Island
Parrsboro Shore
North Mountain
Robinson Projection
ArcGIS 8 Development Team
March 2000
Source: ESRI Data & Maps CD
Created in ArcGIS 8 using ArcMap

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