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Abstract

This paper presents a model for the evaluation of coastal zone sites in conjunction with supporting decision making on the use of potential sites for aquaculture as well as other site activities including commercial fisheries, and as reserves for natural resources. The decision support model captures site specific data in the form of a geographical information system that overlays selected geographical regions with natural resource dynamics, habitat, commercial activities including aquaculture, and influence plumes including toxicology. Descriptive data for selected regions including system overlays and interactions are then evaluated to provide input to a multicriteria analysis that positions decision makers with respect to the relative importance of resources, habitat, commercial activities, and influence plumes. The model compares alternative evaluations of selected regions among diverse users, as well as providing a group decision evaluation procedure to assist in coastal zonal governance decision makers such as the awarding of fish farm site applications. The model is applied to the coastal zone of Grand Manan Island, New Brunswick situated in the Bay of Fundy.

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Table of Contents

List of Figures

List of Tables

Table and Description..Page Reference

1 INTRODUCTION

According to FAO (1990), aquaculture is defined as "the farming of aquatic organisms, including fish, molluscs, crustaceans, and aquatic plants. Farming implies some form of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators, etc. Farming also implies individual or corporate ownership of the stock being cultivated. For statistical purposes, aquatic organisms which are harvested by an individual or corporate body which has owned them throughout their rearing period contribute to aquaculture, while aquatic organisms which are exploitable by the public as a common property resource, with or without appropriate licenses, are the harvest of fisheries."

As for "coastal", it is summarized as including the shore land influenced by the sea, the water column and the seabed extending to edge of the continental shelf (Sorensen and McCreary 1990). Therefore "coastal aquaculture" should cover land-based and water-based brackish and marine aquaculture practices (Barg 1992).

Just as domesticating promoted our ancestors into agriculturalists on land, fish farming may change us from hunters and gathers on the seas into marine pastoralists. The benefits of coastal aquaculture have been widely recognized. These benefits include increased income, employment, foreign exchange earnings and improved nutrition (Pullin 1989). The expansion tendency of aquaculture all over the world of course includes the expansions taking place in the Bay of Fundy, one of the best aquaculture regions in Canada.

However, "although there is potential for development in many areas, aquaculture may increasingly be subject to a range of environmental, resource and market constraints. Aquaculture is competing for land and water resources, which in some cases resulted in conflicts with other resource users. Also, there is growing concern about the environmental implications of aquaculture development, comprising the adverse effects of aquaculture operations on the environment as well as the consequences of increasing aquatic pollution affecting feasibility and sustainable development of aquaculture" (Barg 1992).

Brindley (1991) pointed out that "the more is not always the better". It is necessary to evaluate coastal aquaculture from different positions and points of view. A multi-disciplinary team, ideally including specialists from the same culture, should look at economic, social, cultural and environmental aspects to assess all possible impacts.

Successful coastal aquaculture management requires deliberate decisions. Management decision must be made at all levels from the resources distribution, habitat situation, pollution and commercial activities to different stakeholders' benefit. It is a complex and difficult process. For a simple example, setting a fish farm in the Bay of Fundy, New Brunswick, the general process is as follows

(1) The applicant propose a setting fish farm application to the local Government
(2) Local Government organizes specialists including federal scientists to examine the corresponding conditions, problems and possible influences of setting fish farm and check whether this setting violates regulations of Provincial and Federal Governments
(3) Provincial Government approves or refuses the application

The difficulties of this process are mainly concentrated on the second step. How to evaluate the feasibility of setting the fish farm is full of challenges. It needs much related information which includes natural conditions, resources using, possible conflicts and the impacts of near and far future etc.

In view of the difficulties of decision making, it is helpful to establish a Decision Support System (DSS) to optimize the decision making. In this research, much attention will focus on the Decision Support System of coastal aquaculture which is quickly developing in the Bay of Fundy region of Atlantic Canada. Since various impacts of coastal aquaculture may cover both the natural world and human society, one of the main challenges comes from how to integrate and synthesize the analysis of various information sources that may be from the fields of Biology, Ecology, Toxicology, Habitat, etc., i.e., the natural world; or from human society including the study of economics, industrial commercialization, community development, and federal and provincial government regulations, that are all part of the human environment system.

The objectives of this research are listed as follows:

1. to search key factors in making aquaculture site evaluations and in providing viable, systemic alternatives for decision makers;
2. to find effective ways to summarize and disseminate "natural" and "human" information related to coastal aquaculture systems;
3. to develop a prototype decision support system (DSS) for the spatial evaluation of marine sites for the consideration of multiple participants in the decision-making process; and
4. to delineate an integrated view for the farming of specific species in the Bay of Fundy region of Atlantic Canada.

To this end, the detailed methodology contains applications of Geographical Information Systems (GIS) and Object Linking and Embedding (OLE) techniques to integrate multidisciplinary information and to display it dynamically on electronic maps. The research will also use spreadsheet and the pairwise comparison techniques of multicriteria analysis to study the trade-offs in the coastal aquaculture system according to the different participants in the policy making arena. The research also develops prototype software that utilizes existing software products like the multicriteria decision making methods in *Expert Choice 2000* and the specifically developed program code to perform simulation for exploring the relationships among different factors and to confirm analyzing results.

Final results will be presented and illustrated by operational interfaces, reports, maps, graphs, and site evaluations and rankings for multiple participants applied to the case of the island of Grand Manan in the province of New Brunswick.

1.1 Plan of the Thesis

This thesis is composed of the following major parts:

- Chapter 1 (above) gives a general introduction of the coastal aquaculture, discusses the related problems and challenges in this field.
- Chapter 2 reviews the general situation including the new techniques and methods being applied in coastal aquaculture; annotates the process and methods with examples from the literature.
- Chapter 3 describes and illustrates the methodologies used in this study.
- Chapter 4 presents the modeling and analysis of alternative experiments for the coastal aquaculture near Grand Manan Island; the expected results are also evaluated.
- Chapter 5 concludes this study and recommends future work.

Finally, the Bibliography lists the cited references as well as many important relevant literatures in this research. Appendix I and II show the detailed data and results which are referred to in the thesis text, but are too lengthy to be included fully in the text.

2 BACKGROUND AND LITERATURE REVIEW

According to the Fish and Agriculture Organization (FAO) statistics, aquaculture's contribution to global supplies of fish, crustaceans and molluscs continues to grow, increasing from 3.9 percent of total production by weight in 1970 to 27.3 percent in 2000 (Fletcher and Neyrey 2003). Aquaculture is growing more rapidly than all other animal food producing sectors. Worldwide, the sector has increased at an average compounded rate of 9.2 percent per year since 1970, compared with only 1.4 percent for capture fisheries and 2.8 percent for terrestrial farmed meat production systems (Fletcher and Neyrey 2003).

In Canada, it is said that the earliest aquaculture was practiced by aboriginal people to transfer fish between different rivers and streams. By 1950, in order to enhance wild stock and non-commercial stock expansion, federal and provincial governments had established a hatchery network and produced about 750 million freshwater fish and freshwater spawning fish annually (CAIA 2003). In 1970s, aquaculture as a commercial activity began in Canada, and quickly and widely spread all over the country by the 1980s. Now, it has become an industry, an important food product producer and employment provider. According to Statistics Canada, in 1999, the revenues obtained from aquaculture industry were $621.4 million and in 2000, it reached $674.1 million. The annual increasing rate is 8.5%. New Brunswick and British Columbia accounted for 83.2% of all aquaculture revenues in 2000. The total aquaculture gross output - including sales, subsidies and growth in inventories was $722.47 million in 2000, up $25.1 million from 1999.

However, with the rapid development in aquaculture, many new challenges such as environment pollution, ecological variation, habitat change of aquatic animals and many impacts on economy, society, etc., have appeared. Since more is not always the better, it is necessary to consider both various input and output and to evaluate comprehensively every aspect impacted by aquaculture. The conclusion may be quite different in accordance with different standards, for example, the different spatial or temporal scales (e.g., short-term or long-run), or the different positions of social groups (e.g., industry views may differ from community or environmental groups' views). Therefore, the intent of this analysis is to make clear what key factors are in coastal aquaculture, to collect related information, and to find effective methods to do integrated analysis.

In light of the characteristics of coastal aquaculture, we utilize modern techniques and effective methods to establish a framework model which provides an easily operated way to collect data, integrate information, and visualize the results. Accordingly, the intent of this research is to fully understand the aquaculture problem; to explore possible integrating techniques in the complex environment, and to find multicriteria judgment methods that recognize the participation of many players in aquaculture decision making.

In the following sections, the content and challenges of coastal aquaculture modeling and analyses are examined from the literature review. These include reviews on coastal aquaculture modeling applications (Section 2.1) and geographic information systems approaches (Section 2.2), and a review of methods applied to multicriteria decision making and the Analytic Hierarchy Process (AHP) (Section 2.3) and, finally, integrated modeling using state-of-the-art computer programming methods such as VB.NET (Section 2.4). GIS, AHP and VB.Net are all important as very useful tools and methods for the current research.

2.1 Coastal Aquaculture

Coastal aquaculture is receiving increasing attention. This is mainly due to next two reasons:

(1) Many traditional commercial fisheries are becoming fully exploited;

(2) Managing dynamic migrating fish stocks is very difficult (Lane and Stephenson 1998a). Traditional fisheries are based on stocks of wild animals living in the natural environment. Theses stocks cannot be controlled in the direct and positive way that the farmer or rancher controls spatially determined domestic stocks. In response to the pressures of finite resources and

increasing consumption, aquaculture is becoming more and more important in the supply of products from the sea that can be more controlled and managed. As Allen et al (1992) pointed out in the book *Bioeconomics of Aquaculture,* "it is increasingly evident that if we wish to maintain aquatic foods in our diet, we must intervene in natural processes, manage dwindling resources carefully, and utilize those not yet exploited."

For different coastal regions, the contents of coastal aquaculture may be different. However, it has great potential for the production of food and generation of wealth for people living in coastal areas. In Canada, Atlantic and Pacific Salmon, Rainbow trout, tilapia, Arctic char, mussels, oysters, clams and scallops are the basic species to be commercially cultured. New species such as halibut, cod, wolfish, striped bass, eel, haddock, abalone, geoducks, quahaugs and sea urchins are in the experimental stages of development (CAIA 2003).

At the same time, how to face the concomitant negative impacts of running coastal aquaculture and to find good solutions to these impacts is becoming more and more pressing. The main challenges of aquaculture result from:

(1) the affected aspects and impacts of fully developed and running costal aquaculture operations are not completely clear, e.g., conflict with other fisheries and gear types, overuse of lower trophic level fish protein to grow less aquaculture protein than input;

(2) the vulnerability of aquaculture to poor water quality and aquatic pollution, caused by industrial, domestic, agricultural and aquaculture (i.e., its own) wastes; and

(3) rapid overdevelopment, where the undoubted successes of the sector have been tarnished by environmental and resource use issues, social problems, diseases, and in some cases, marketing problems are often associated with the coastal aquaculture development (GESAMP 2001).

It has been recognised that coastal aquaculture is characterized by complex interactions between resources, ecosystems and resource users but with no simple applicable models to examine those challenges. The most appropriate approach will depend upon a wide range of local factors and a more integrated approach is needed to promote sustainable development in the coastal zone.

According to Nath et al. (2000), planning activities to promote and monitor the growth of aquaculture in specific areas inherently have a spatial component which include biophysical and socio-economic characteristics. Biophysical characteristics may include criteria pertinent to water quality (e.g., temperature, dissolved oxygen, alkalinity/salinity, turbidity, and pollutant concentrations), water quantity (e.g., volume and seasonal profiles of availability), soil type (e.g. 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 resource uses, market conditions (e.g., demand for fishery products and accessibility to markets), infrastructure support, and availability of technical expertise. Therefore, a natural consideration is to deal with the biophysical characteristics and socio-economic characteristics separately, and then combine them to form scientific advice to decision-makers.

The key point here is the spatial component, which is reminiscent of applying Geographic Information Systems (GIS), a powerful tool for conducting spatial component analyses. Spatial information needs for decision-makers who evaluate biophysical and socio-economic characteristics as part of aquaculture planning efforts are illustrated by Kapetsky and Travaglia (1995). Moreover, it is often the case that governmental agencies involved with issuing new aquaculture permits need to perform spatial analysis on a proposed site to assess its potential environmental, economic and social impacts on other locations. This situation is analogous to the need for monitoring existing operations in terms of environmental and/or other impacts (Nath et al. 2000). As noted by Osleeb and Kahn (1988), these decision support needs cannot be effectively addressed without the use of GIS. Finally, Kapetsky and Travaglia (1995) also point out that the individual investor interested in aquaculture development also requires spatial information particularly at the time of site selection from among a range of alternative locations with different biophysical and socio-economic characteristics. GIS, discussed in the next section, is potentially a powerful tool for assisting this class of decision-makers, and is already being used effectively for such purposes (Carswell 1998; LUCO 1998; Arnold et al. 2000).

2.2 Geographic Information Systems (GIS)

In the strictest sense, a GIS is a computer system capable of assembling, storing, manipulating, and displaying geographically referenced information, i.e., data identified according to their physical, spatial locations. We also can regard the total GIS as including operating personnel and the data that are part of the system.

Generally, GIS is used to deal with matters or information related to spatial components. Since about 85% of existing databases contain some sort of geographic information or spatial components (MapInfo 2002a) and because strong GIS functions are continuously developed, more and more people gradually realize that GIS, including its summarizing ability, its visualizing characteristics and its operating easiness, has an important role to play. Now, GIS is being used in many different areas and in multiple fields for description and analyses.

Quantitative GIS applications can be found in various disciplines (MapInfo 2002c; ArcInfo 2001). GIS applications in aquaculture have been well reviewed and documented by Kapetsky and Travaglia (1995), Ross (1998) and Nath et al. (2000). Some cases, which have the perspective of applications for spatial decision support in aquaculture (an important theme of this thesis research), have also been tabled by Nath et al. (2000) based on the different scales ranging from local areas (i.e., a small bay), to sub-national regions (i.e., individual states/provinces), to national and continental expanses (see also Table 2-1). Among the cases in Table 2-1, two Canadian studies, shellfish and salmon aquaculture in British Colombia and shellfish culture in Prince Edward Island are listed.

Table 2-1 GIS applications in aquaculture according to the kind of assessment and scale of study (adapted from Nath et al. 2000)

Purpose	Geographical region	GIS Software	Reference
Large area assessments (low resolution)			
Warm water aquaculture	Continental Africa and Madagascar	ERDAS and ArcInfo	Kapetsky (1994)
Inland aquaculture	Latin America	ArcInfo	Kapetsky and Nath (1997)
Inland aquaculture	Continental Africa	ArcInfo	Aguilar-Manjarrez and Nath (1998)
Medium area assessments (medium resolution)			
Trout farms	England and Wales	GIMMS	Meaden (1987)
Carp culture (ponds)	Pakistan	Spreadsheet	Ali et al. (1991)
Tilapia and Clarias culture in ponds	Ghana	ArcInfo and ERDAS	Kapetsky et al. (1990a)
Small reservoir fisheries	Zimbabwe	ArcInfo	Chimowa and Nugent (1993)
Shrimp culture in ponds; fish culture in cages	Johor (State) Malaysia	ERDAS	Kapetsky (1989)
Fish and crayfish farming in ponds	Louisiana (State), USA	ELAS	Kapetsky et al (1990b)
Pond and cage culture	Tabasco (State), Mexico	IDRISI	Aguilar-Manjarrez (1992)
Fish, shrimp and mollusk culture	Tunisia	ArcInfo	Ben Mustafa (1994)
Land aquaculture	Sinaloa (State), Mexico	IDRISI	Aguilar-Manjarrez and Ross (1995)
Shellfish and salmon aquaculture	British Columbia (Province), Canada	ArcInfo	LUCO (1998)
Small reservoir fisheries	Southern Africa	MapInfo, Windisp	ALCOM (1998)
Small area assessments (high resolution)			
Catfish farming	Franklin County, Louisiana, USA	ELAS	Kapetsky et al. (1988)
Shrimp and fish farming in ponds	Gulf of Nicoya, Costa Rica	ELAS	Kapetsky et al.
Brackishwater aquaculture	Lingayen Gulf, Philippines	SPANS	Paw et al. (1994)
Shellfish culture	Prince Edward Island, Canada	CARIS	Legault (1992)
Salmonid cage culture	Camas Bruaich Ruaidhe Bay, Scotland	OSU-MAP for-the-PC	Ross et al. (1993)
Shellfish culture	Sepetiba Bay, Brazil	IDRISI	Scott et al. (1998)
Shellfish culture	Indian River Lagoon, Florida, USA	IDRISI and ArcView	Arnold et al. (2000)

Nath et al. (2000) selected 4 cases for detailed review and gave pertinent comments according to a definite format including (a) Source of the work; (b) Objectives; (c) Target decision support audience; (d) Geographic area and scale of analysis; (e) Analytical methods and results; and (f) Comments on limitations of the approaches used, possible enhancements, and actual use for decision making etc.

In the case of "Site selection for salmonid aquaculture", Ross et al. (1993) used a successive screening process for different criteria identified to be of importance in evaluating aquaculture sites. These criteria included depth, current velocity, salinity, dissolved oxygen and temperature etc. All of these criteria were analyzed and then by filtering the unimportant parts they ultimately obtained 4 key criteria– depth, wave height, current intensity, and salinity. Each criterion was used to evaluate the entire bay on the base topographic map and named one layer. Finally, all layers were overlaid to show the potential for salmonid cage culture. Nath et al. (2000) pointed out that in this case study, the advantage of using GIS for site selection were obvious. However, "Ross et al. (1993) only used biophysical characteristics in this process. A more robust site selection strategy as developed in this thesis would also include detailed analysis of economic (e.g. infrastructure support, availability of and distance to markets, etc.) and social factors (e.g. impacts on coastal communities). "

In the case of "Shellfish and finfish aquaculture management in British Columbia, Canada, (Carswell 1998; EAO 1998; LUCO 1998)", a fully integrated information system - British Columbia Aquaculture System (BCAS) was developed. Applying the BCAS and based on 14 criteria proposed by Cross and Kingzett (Cross and Kingzett, 1992; Cross, 1993), a module is established to evaluate the Site Capability Index (SCI) for shellfish. The 14 criteria are organized into three subgroups:

(1) direct impact on growth: water temperature, chlorophyll A (a measure of food availability), fetch, and exposure;
(2) direct impact on survival: suspended sediments, tidal flow, fouling/disease/predators, substrate and beach slope (the latter two variables are used only for bottom culture); and

(3) indirect impact of water chemistry on growth/survival: salinity, dissolved oxygen, and pH.

For finfish, 12 key biophysical criteria (Caine 1987) are applied in the following 3 ranked list to build the module. They are:

(1) first order (factors directly affecting fish growth and survival): water temperature, dissolved oxygen, salinity, and phytoplankton.
(2) second order (factors that may have long term detrimental effects on fish survival): pollution, currents, depth, site physiography, and hydrology (freshwater flow); and
(3) third order (risk factors that impact the physical and financial condition of operations, but which can be mitigated by suitable culture techniques): predators, marine plants/fouling organisms, wind and wave action.

In BCAS, factors within each of these groups are evaluated and categorized into suitability classes (see alsoTable 2-2).

In addition to the rating classes shown above for the ecosystem inventory, sites that fall outside the range of values presented are classified as not acceptable for finfish culture.

All these cases provide good references for this study. Around how to do spatial analysis, it seems forming a common way, that is, determining the geographical area, establishing some criteria to scale the properties of studied objects, overlapping the objects with different properties to get comprehensive conclusions. In the process, what GIS applications should be adopted is noteworthy.

There are many GIS software tools which can be used to do spatial analysis (GISCafe 2004). In Table 2-1, Nath et al. (2000) listed some of them which included ArcInfo, ERDAS, GIMMS, Spreadsheet, ELAS, IDRISI, MapInfo, Windisp, SPANS, CARIS, OSU-MAP for-the-PC. Among these tools, ArcInfo (ESRI 2004a), MapInfo (MapInfo 2004) and IDRISI (Clark Labs IDRISI Software 2004) are the most popular commercial GIS software.

Table 2-2 Source layers for biophysical criteria, and ratings used in BCAS to evaluate the capability of waterways to support salmonid cage culture (table adapted from Caine 1987)

Source layer	Rating		
	Good	Medium	Poor
Summer Tempture (°C) **Winter Tempture (°C)**	10-15 >7	16-21 5-7	>21 <4
Dissolved oxygen (% saturation)	100%	79	57
Salinity (ppt)	>24	15-24	<15
Plankton	No record of harmful blooms	Infrequent harmful blooms	Frequent and lethal blooms
Pollution	No sources nearby	Nearby, low level sources	Within high pollution areas
Currents (cm/s) **Slack water** **Peak flows**	 10-15 10-50	 2-10 50-100	 <2 100-200
Low tide depth (m)	>50	20-49	10-19
Site Physiography **Slope** **Substrate**	 >30 degree Rock, sand or gravel	 15-30 Sand or mixed rock	 <15 Mud or organic ooze
Hydrology (freshwater lens depth in m)	<1	1-4	>4
Predators	None	Close to sea lion haulouts with many avian/mammal predators	Nearby sea lion rookeries and haulouts; bird colonies nearby and many mammal predators
Marine plants and fouling organisms	Low levels of fouling organisms; no kelp	Moderate levels of fouling organisms; kelp nearby	High levels of fouling organisms; kelp onsite
Winds and waves/snowfall and freeze over	Site not exposed to polar outflows; wave height < 0.6 m	Partial exposure to polar outflows; wave height 0.6-1.0m	Complete exposure to polar outflows; wave height > 1.2m

ESRI's ArcInfo should be ranked as first not only because of its current market dominance but also because of its powerful functionality. ESRI has been referred to as "GIS's Microsoft". However, its expensive price (ArcInfo 8.0.x Floating License is $7,100, ESRI (2004b)), and higher requirements for computer hardware, force some users to select other smaller and cheaper products. IDRISI is the industry leader in raster analytical functionality and its latest release, *IDRISI Kilimanjaro*, is priced as $995 for one single user license (Clark Labs IDRISI 2004). The latest version of MapInfo Professional v7.5, claims to be the industry's leading business mapping solution, had a price of about $1495 (Primus Geographics 2004). Generally, the latest releases of these GIS software packages consider compatible problems and prepare corresponding functions to allow data exchange between different packages.

For this study, which GIS software to use depends on the anticipated usability of the prototype model to be developed. Given the relative ease of transferability of the data between different GIS applications, it is comparatively free to select existent applications. However, since most utilized data available from the St. Andrews Biological Station are produced for display in MapInfo, and since the users there are readily familiar with this product, in order to maintain the convenience of exchanging results, MapInfo v7.5 was selected as the development software for this research (see also the next section on research methods for details).

There are many decision support tools which could be used to aid the evaluation of coastal aquaculture. Richards (2002) classified these tools as "Ways of Choosing" which included the Analytic Hierarchy Process (AHP), Conflict Analysis, Criteria Rating Form and Weighted Ranking, Gap Analysis, Importance / Performance Matrix, Quantitative Decision Making, Strategic Assessment Model, Strategic Assumptions Surfacing and Testing, as well as nine different approaches to making a Strategic Choice. These different methods are directed toward and are therefore appropriate to different decision tasks although some of these tasks are recognized to be overlapping.

In this study, integrating different evaluations for the same extracted data in a special area is one of important tasks. Considering the process is involved the comparison of decision elements which are difficult to quantify, the multicriteria evaluation is therefore adopted as the candidate method for decision support. The practical process is employed AHP.

2.3 Multicriteria Decision Making and Analytic Hierarchy Process (AHP)

Multicriteria decision making is a process of making decisions based on many characteristics, often contradictory, called criteria. It is generally assumed that the decision maker has to choose among a set of different alternatives and accordingly has to be content with a compromising solution. Some techniques such as Multi-criteria Analysis (MCA) or Multi-criteria Evaluation (MCE) are developed to aid the decision making process (Bana e Costa, 1990; Munda, 1995; Cal et al., 1999; Chakhar and Martel, 2003).

Roy (1996) postulates that MCA is "a decision-aid and a mathematical tool allowing the comparison of different alternatives or scenarios according to many criteria, often contradictory, in order to guide the decision maker(s) towards a judicious choice". Proctor (1999) believes MCE is "a means of simplifying complex decision making tasks which may involve many stakeholders, a diversity of possible outcomes and many and sometimes intangible criteria by which to assess the outcomes."

Whether MCA or MCE is being considered, they are available if the decision is dependent on multiple interactional criteria. They have been both applied to a great deal of practical problems by public planners in such areas as the siting of health facilities, motorways and nuclear reactors (Massam 1988). Decision making in the field of coastal aquaculture is comparable to these public problems - complicated, many interactive factors or conditions, etc.

Applying these different methods, decision makers usually carry out several sequential steps:
(1) Identify the feasible alternatives;
(2) Identify the criteria by which to judge these outcomes;
(3) Apply appropriate weights on each of the criteria which reflects their particular preferences;
(4) Assess each of the alternatives based on this method and obtained information.

The Analytic Hierarchy Process (AHP), one of the more widely used multicriteria methods (MCA or MCE), is reviewed here and employed in this study.

AHP is a logical, structural framework that improves the understanding of complex decisions by decomposing the problem into an explicit multiple criteria hierarchical structure (Saaty 1980). The procedure is captured in the well-used software package *Expert Choice 2000*. The incorporation of all relevant decision criteria, and their pairwise comparison allows the decision maker to determine the trade-offs among prespecified objectives in a hierarchy of objectives and criteria. The application of AHP explicitly recognizes and incorporates the knowledge and expertise of different participants in the priority setting process, by making use of their judgments and trade-offs among objectives and criteria – subjective and objective. The AHP model is based on the three principles of: (1) decomposition of the multicriteria decision problem, (2) relative comparison of the criteria and the known alternative decisions, and (3) synthesis of the priorities and ranking of the alternatives.

The structured AHP process has a major impact on the understanding of the problem by all participants of the factors that influence it. Besides providing a ranking of projects, the process provides profound insight in the art of complex decision making and encourages the multiple participants to pool their knowledge and expertise to arrive at a preferred decision alternative (Saaty 1994).

It is necessary to stress that the ultimate purpose of this study is to provide decision makers with a supporting structure. As Traynor (2003) pointed out in the paper "Why Are Geographic Information Systems Hard to Use?" it cannot be expected that every decision maker has sufficient knowledge of GIS; is computer-literate; and could invest sufficient time to become a specialist to do the trivial analysis. Therefore providing simple, ease-to-use computer interfaces which can directly support the users' tasks and protect them from having to know about detailed information such as datum storing or map drawing is very essential. This modeling requirement actually requires that various data be integrated, and that conducting specific applications be as a single unit or package which is managed accordingly. Model development using Microsoft's Visual Studio .Net, discussed further below can help to achieve this requirement easily.

2.4 Visual Studio .Net and Decision Support System (DSS)

Microsoft declares that "Visual Studio .NET is the comprehensive development tool for rapidly building and integrating XML Web services and applications. Visual Studio .NET offers you a highly productive environment in which to develop a broad range of applications that run on the new Microsoft .NET platform. Using the secure and high-performance Microsoft .NET Framework run-time environment, Visual Studio .NET gives you powerful tools for designing, building, testing, and deploying XML Web services and applications as well as sharing best practices and guidelines in a team environment. " (Microsoft 2004)

To make an integrated developing application for GIS and AHP together for this research in the aquaculture application, it is recognized that the powerful tools of Visual Studio .Net are helpful to build and integrate Windows-based applications in a seamless, integrated modelling framework. Since Visual Basic .NET, Visual C++ .NET, Visual C# .NET, and Visual J# .NET all use the same integrated development environment (IDE), which allows the sharing of tools and facilitates in the creation of mixed-language solutions, the selection of the language is not important. Considering that Visual Basic is very relevant as an interface design, that it is compatible with MapInfo, and that there is a lot of ready-made reference code, the logical choose of the developing language for this research is VB.Net.

Figure 2-1 shows the integrated development environment of VB.Net, where the interface of a project named FindZip is opened in the middle working area. VB.Net provides a lot of tools such as Button, Label, TextBox, MainMenu etc. to create different control keys conveniently. Double clicking the created keys or work space, the behind code window can be opened to add necessary programs. Figure 2-2 shows the code model of the IDE of the VB.Net. Figure 2-3 An example of using OLE and VB.Net to develop MapInfo's applications. If a 5-digit zip-code is input in the text window, the map will move automatically to make the corresponding area locate at the middle of the map window.

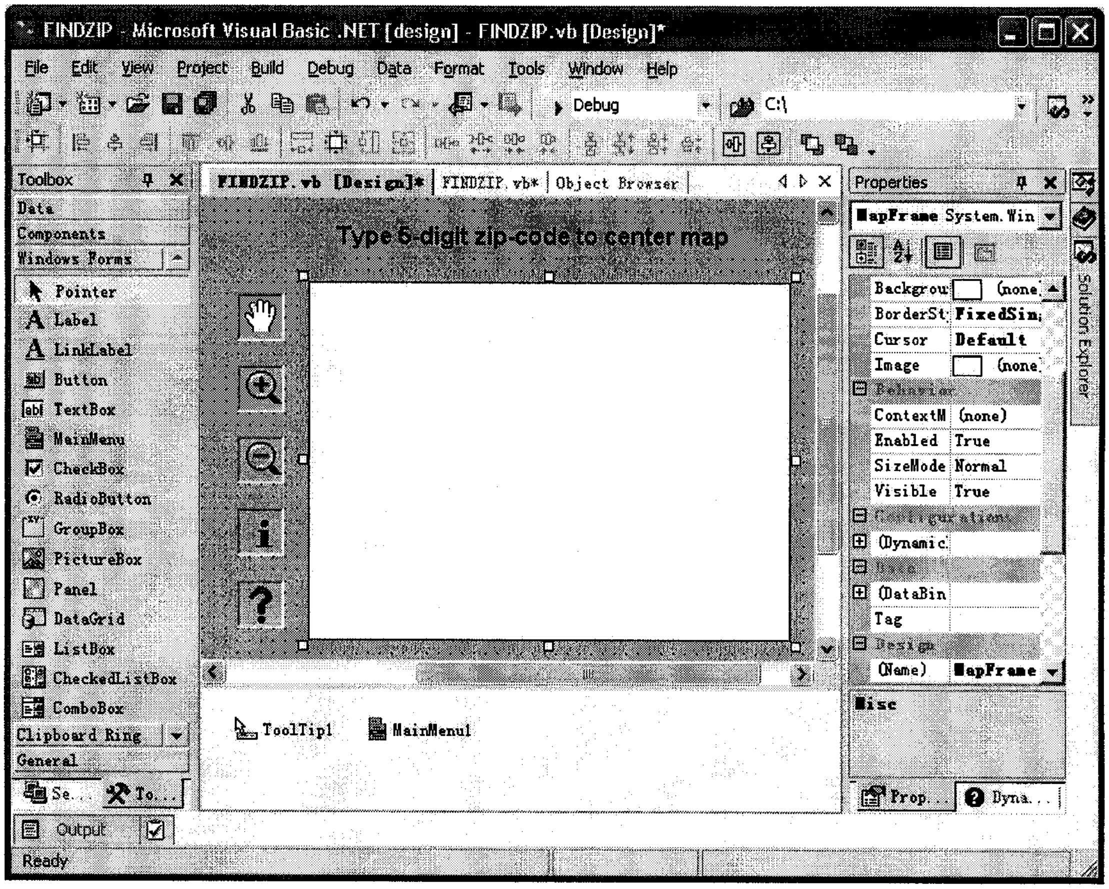


Figure 2-1 The integrated development environment (IDE) of VB.Net, where the interface of a project named FindZip is opened in the middle working area. Its left side is the provided Toolbox; its right side is the Properties window. No matter VB, C++, C# or J# are used, the IDE is the same.

The Decision Support System (DSS) can be considered as a specific computerized information system that supports decision making activities. Usually, a DSS is an interactive software-based system intended to help decision makers to access, compile raw data and combine known knowledge to identify and solve problems and make decisions. Most DSSs may present information graphically and some of them may include expert system or artificial intelligence.

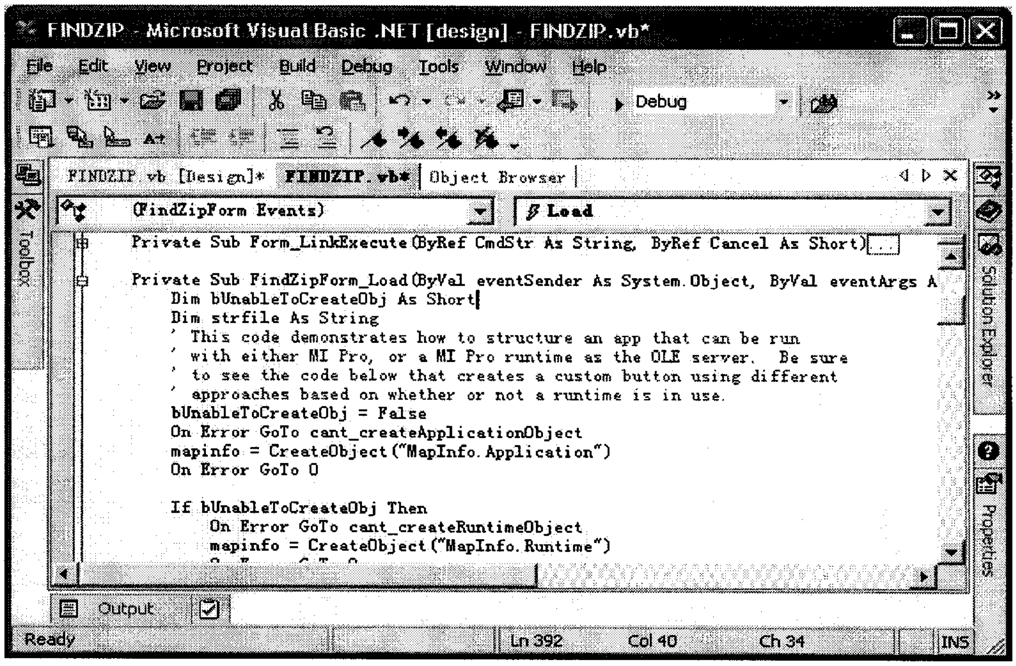


Figure 2-2 The code model of integrated development environment (IDE) of VB.Net

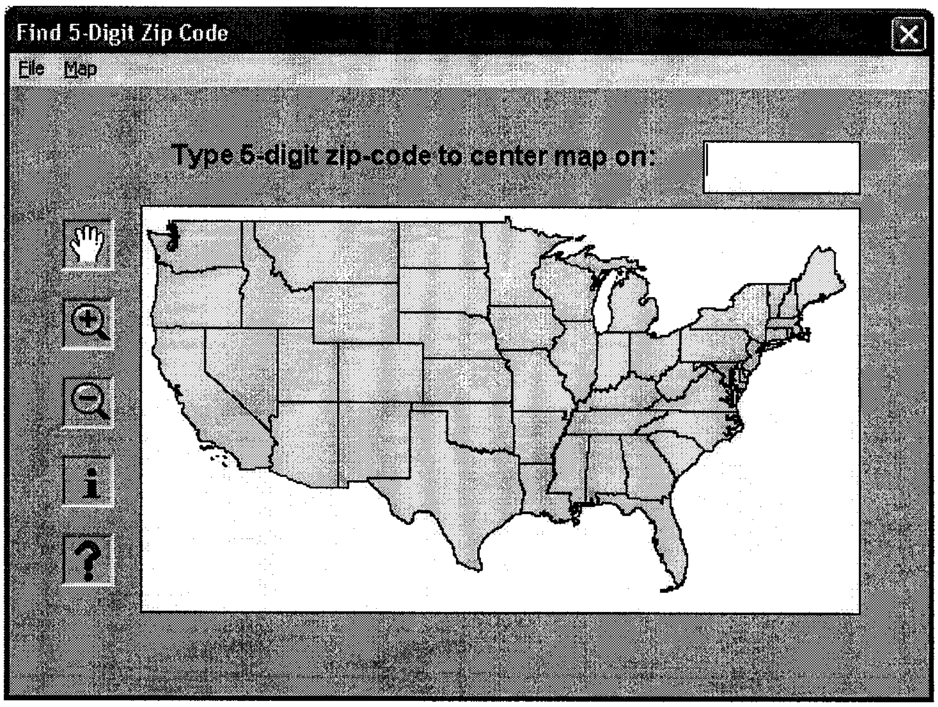


Figure 2-3 An example of using OLE and VB.Net to develop MapInfo's applications. If a 5-digit zip-code is input in the text window, the map will move automatically to make the corresponding area locate at the middle of the map window.

The accepted and precise definition of DSS is difficult to find because it varies depending on the author's point of view (Druzdzel and Flynn, 1999). For example, Turban (1995) defines it as "an interactive, flexible, and adaptable computer-based information system, especially developed for supporting the solution of a non-structured management problem for improved decision making. It utilizes data, provides an easy-to-use interface, and allows for the decision maker's own insights." However, for Keen and Scott Morton (1978), "DSS are computer-based support for management decision makers who are dealing with semi-structure problems." Keen (1980) claims "there can be no definition of *decision support systems*, only of *decision support*". But for Sprague and Carlson (1982), DSS are "interactive computer-based systems that help decision makers utilize data and models to solve unstructured problems".

Also, according to Keen and Scott Morton (1978), the concept of decision support has evolved from two main areas of research: the theoretical studies of organizational decision making done at the Carnegie Institute of Technology during the late 1950s and early 1960s, and the technical work on interactive computer systems, mainly carried out at the Massachusetts Institute of Technology in the 1960s. In the middle of the 1970s, the concept of DSS became an area of research of its own. Since 1980s, group decision support systems (GDSS), data warehousing and on-line analytical processing (OLAP) appeared one after another. Now, Web-based analytical applications are introduced. In the field of GIS, the IDRISI GIS starts to support the AHP method from its Version 4.1.

Kendall and Kendall (1999) listed a series of DSS methods which included

(1) Weighing method
(2) Sequential elimination by lexicography
(3) Sequential elimination by conjunctive constraints
(4) Goal programming
(5) Analytic Hierarchy Processing (AHP)
(6) Expert systems
(7) Neural nets

(8) Recommendation systems

For example, the Weighing Method was explained as “assigning various components of the alternatives a certain percentage and multiplying numerical scores for the components by the percentages”. The Sequential elimination by conjunctive constraints means that “the decision maker sets constraints and eliminates alternatives that do not satisfy the set of all constraints”. As for AHP, they pointed out that it “requires decision makers to judge the relative importance of each criterion and indicate their preference regarding the importance of each alternative criterion”. They also stated that AHP “has an ease-of-use advantage over goal programming” since “The decision maker does not have to be skilled at formulating goal equations” and “does not have to be knowledgeable about goals and priorities”. They also explained the main steps in AHP applications. It is clear they attached importance to AHP.

Integrate of GIS and AHP is important for this research.

As Chakhar and Martel (2003) pointed out in their paper “Enhancing Geographical Information Systems Capabilities with Multi-Criteria Evaluation Functions”, even though numerous practical applications have shown that GIS is a powerful tool of acquisition, management and analysis of spatially-referenced data, most of current OR/MS specialists share the impression that the GIS is a limited tool in spatial decision-aid domain. This is due essentially to its lack of more powerful analytical tools enabling it to deal with spatial problems involving several parties with conflicting objectives/criteria. The remedy suggested by some researchers is to integrate the GIS with different OR/MS tools.

One realistic solution is to incorporate the MCA method into the GIS to form a GIS-MCA integration. Here GIS provides a powerful tool for managing spatially referenced data and MCA supports modeling spatial problems.

This study is trying to incorporate MapInfo and AHP and build a MapInfo-AHP DDS.

3 METHODOLOGY AND PROGRAMMING

The goal of this study is to study the coastal aquaculture in the Grand Mann Island area situated in the Bay of Fundy and to provide decision support for problems related to the evaluation of marine sites potentially for aquaculture and its overall impacts. This includes identifying and integrating various multidisciplinary information obtained from different fields or disciplines, summarizing them into regular, quantified and operational criteria and then providing operational advice to all the participants in the decision making system.

Since aquaculture is a field where Man interacts with the natural ecosystem, a reasonable consideration is that possible impacts can be classified into two categories, natural field and social-economic field. With these measurable impacts in hand, the total results can then be summarized.

A framework of the aquaculture evaluation research project has been proposed by DFO scientists, managers, and aquaculture industry participants to represent the integrated nature of the aquaculture problem (DFO 2003). Figure 3.1 shows the proposed DFO framework of the aquaculture study. It consists of three major columns: the left column, middle column and right column, respectively. Each column represents one important aspect of this study and different methodology is adopted to deal with each of these. A detailed description of the framework is given in the following several sections.

3.1 General Framework of Integrated Model

With reference to Figure 3-1, the column in the middle indicates the main steps or milestones of the study.

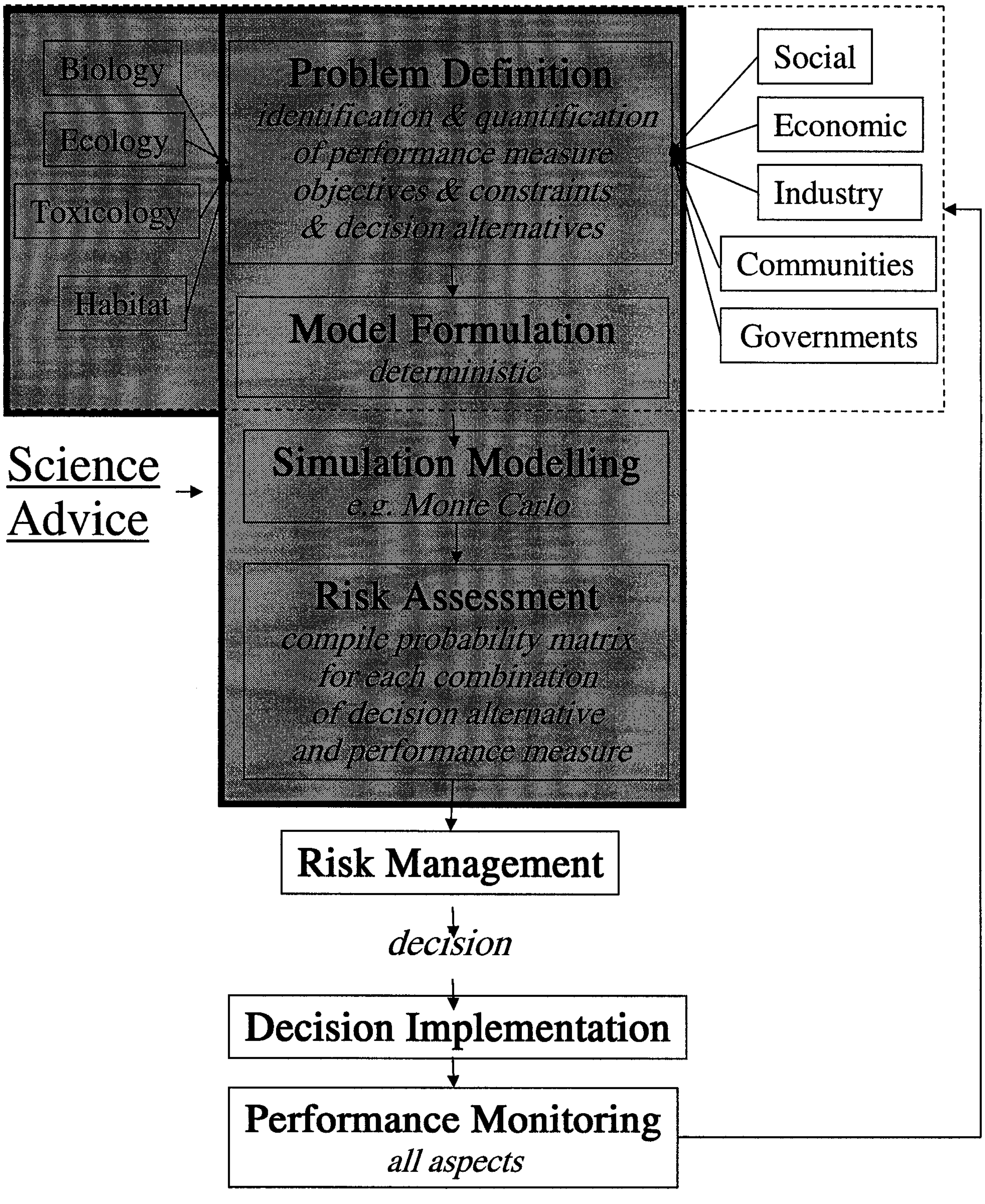


Figure 3-1 Risk Management Framework for Science Advice (DFO 2003)

As the first step, it is necessary to identify study objects and the related main problems. Now the purpose of this research is clear, that is, to provide concrete, operational support to assist policy-making for coastal aquaculture in the Bay of Fundy region. As a simple starting point, Grand Manan Island is selected as the area of application. By interviewing specialists and checking the situation of data collection, this study and prototype model can be expanded to the whole of the Bay of Fundy, e.g., to assist in zoning analysis to evaluate the zones which are particularly suited (or unsuited) to aquaculture development and their possible influences on environment, economy and management, etc of running aquaculture.

The important problems confirm the impacts of coastal aquaculture. Secondly, quantitative measures for the evaluated natural ecosystem and socio-economic components need to be found. In light of accumulated experience including those obtained from inland aquaculture, which has a much longer history than the one of coastal aquaculture, the natural ecosystem is described by the key components of Biology, Ecology, Toxicology and the habitat of wild fish, which is the left hand side column of the Figure 3-1. The socio-economic components contain the social, economic, industry, and community impacts, that is corresponding to the right hand side column of the same Figure 3-1.

As a study example, the 4 components of natural ecosystem around the island of Grand Manan can be further defined in more detail below.

(1) Biology: mainly concerns the distributions of natural resources. Here simply selects several species' distributions to represent this component. They are herring schools daytime staging area distribution and night-time inshore area distribution, lobster molting area and feeding area distribution, scallops population area distribution and urchins population area distribution;
(2) Habitat of wild fish: concerns the habitat situation including rockweed, salt marshes, benthic community description or simplify to bottom, and current flow to represent this component;
(3) Toxicology: concerns the pollution situation. Using chemical A, chemical B and chemical C from fish farm sites to represent this component;

(4) Ecology: concerns the interaction between human commercial activities and environments, e.g., herring weirs, fish farms, lobster traps, scallop dragging, and urchin dragging gear and resource interactions.

Based on these definitions, a unit value - for example, their yields ($) - to evaluate each component or in other words, inventory and value the natural ecosystem.

As for socio-economic components - social, economic, industry, community and government, the following 5 participant groups are defined:

(1) Local communities,

(2) Federal Scientists,

(3) Industrial organizations,

(4) Non Governmental Organizations,

(5) Provincial Governments.

By interviewing or inquiring about the trade-offs among representative members of each group, their ideas about the coastal ecosystem around Grand Manan Island can be summarized. A good way to make quantitative measurements about their ideas is to do paired comparison of multiple objectives as will be discussed in the analysis of the muti-criteria decision making problem discussed later.

Hambrey et al. (2002) showed an example of how to build quantification indices for various factors to measure their influences on marine sites. They used cage culture of salmon as the topical example to analyze the actual and potential environmental impacts of salmon cage aquaculture. As illustrated in Figure 3-2, related phenomena or "activities" were listed and graphically described. Then, for each of these phenomena, quantitative measures were made. Hambrey et al. mainly analysed risks associated with waste food and faeces (including setting solids and suspended solids in the water column, dissolved nutrients), chemical releases, interactions with wild salmon, and a typology of impacts as illustrated.

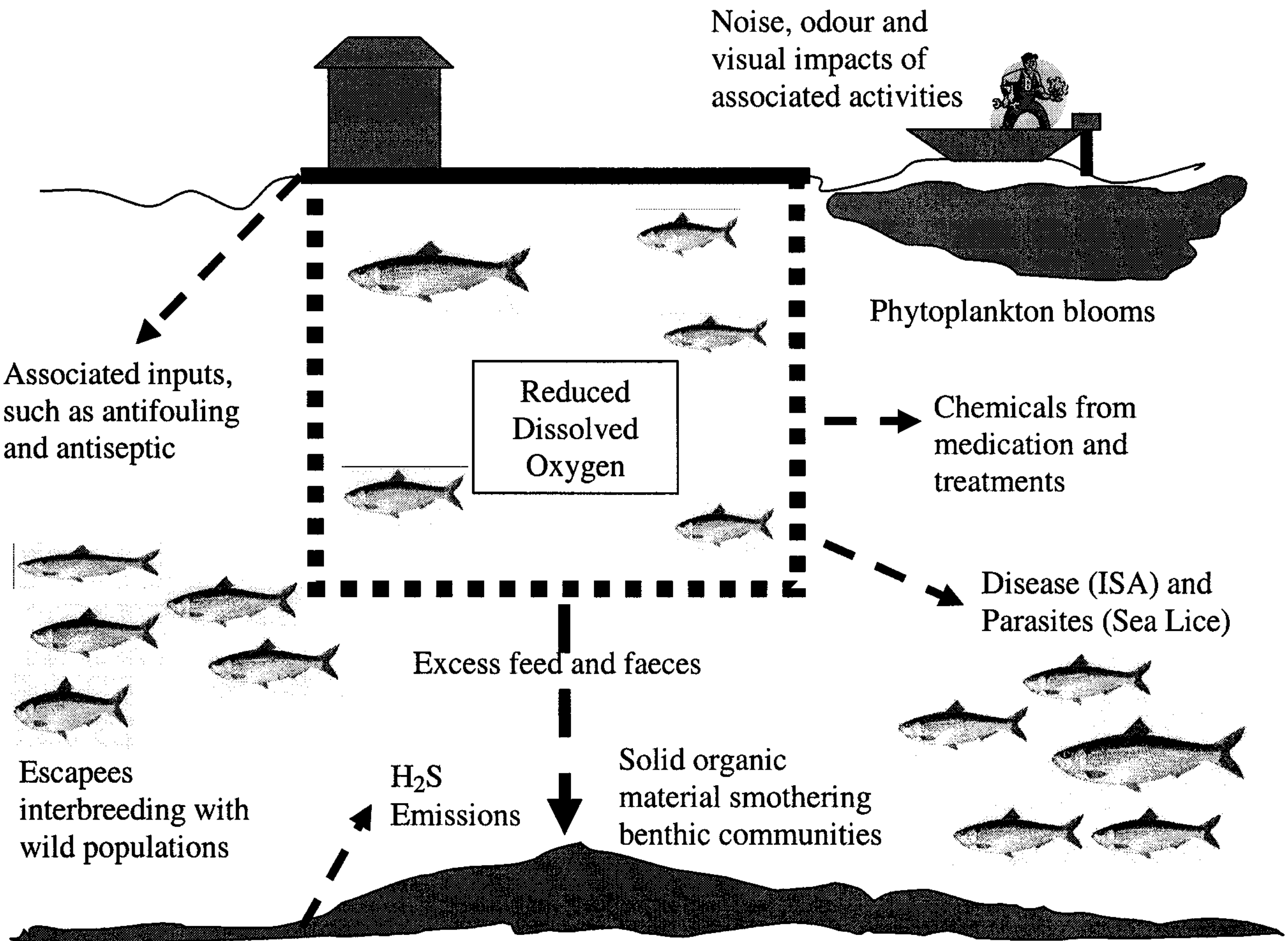


Figure 3-2 Main pathways associated with cage salmonid culture (Adapted and updated from Hambrey et al. 2002).

Obviously, their work only belongs to the left column of Figure 3-1, that is, the direct impacts on the natural environment. However, it is easy to expand this to the right column, that is, the direct impacts on human society. In this research, a similar analysis for the social, economic and industry impacts is followed.

Thirdly, after we identify the various components and construct corresponding quantitative measures of value and performance, a general model is established to describe the main components of marine sites in the Bay of Fundy, specifically around Grand Manan Island. In the general model, some parameters are determined from existing valuation data and calculations; other component values however are difficult to obtain and contain larger uncertainty. In addition, the relationships among different parameters are somewhat subjective. These characteristics require that some estimation be made in the form of simulated data values and value relationships among different parameters. Finally, based on the available data and the simulated results, a set of operational advice from the impact of alternative approaches are made to decision makers.

In view of the importance of how to analyze the impacts on the natural and social environments and in summarizing the total information, a more detailed explanation of the system is required as presented in the following sections.

3.2 Data Integration and GIS

The left hand side column of Figure 3-1 is used to indicate the impact of applying coastal aquaculture to the natural environment. The task here is to use GIS to integrate various natural environment parameters.

Integrating vast data is the strong point of GIS. It is obviously that a map is one of the most effective methods to organize various large numbers of data. A simple map may load unlimited information and that GIS is a powerful tool to deal with the map. Therefore, applying GIS, especially its functions of displaying, overlapping, selecting and extracting data to this research is a consequent consideration.

3.2.1 Data visualization and operation by GIS

As was introduced in Chapter 2, Background and Literature Review, MapInfo is selected as the GIS developing tool in this research. MapInfo is a small but powerful application. Its requirements for memory and hard disk space are not very high (except data, only 150Mb space is required). All its information, whether textual or graphic, is organized in the form of tables and each table is a group of MapInfo files that constitute either a map file or a database file (MapInfo 2002a).

In the GIS, maps are organized into layers. Each layer contains specific information of the whole map and may consist of many map objects such as regions, points, lines, and even texts. Each table displays as a separate layer. Map layers form the building blocks of maps. Once the map of layers has been created, the layers can be viewed in a variety of ways, and may be added, deleted, or reordered.

The first step in using GIS is to prepare the data related to the spatial positions. Usually, these data are a table with coordinate (longitude and latitude) information included. The second step is to upload these data on the screen map. It is actually a process of transferring data records to the elements on the map depending on the coordinate information and the designated project system.

It should be pointed out that in MapInfo, the figure and the table are inseparable. Different pieces or elements in the figure correspond to different lines in the table, i.e., altering the table results in a comparable alteration to the figure. Therefore, users are free to select the figure window or the table window to perform different operations. For example, to move figure pieces or to change shapes using the figure window is convenient, however, if one is selecting elements with some specific characteristics, then using the table window and corresponding SQL (write out) sentence will be more convenient. Both figure window or table window operations can yield the same results.

Overlapping different geocoded figures on the same map is the strong point of any GIS software. MapInfo provides tools to overlap various maps (layers), and it allows users to select specific areas and then to extract all related data (whether overlapped or not) in that area (MapInfo 2002b). For detailed introduction of data integration and MapInfo, please refer to Appendix I –

Data Integration of MapInfo.

The whole process illustrated above shows that GIS software MapInfo has strong capability to integrate, select, and visualize data. This settles the basic of adopting it as the main tools of this study. On the other hand, the complicated operation shows that in order to make this procedure become more practical, MapInfo requires the user to have or to acquire considerable related knowledge because its interfaces support a system architecture view, rather than a view of the user's work (Traynor 2003). This points the direction of this study – simplifying the operation.

3.2.2 Applying GIS to site evaluation

Using the MapInfo GIS, especially its spatial analysis function, any data related to a specific geographical area could be extracted conveniently. In the case of aquaculture, the data may be the area of water in a specific region, various resources reserves, fishery captures, or aquafarm harvest designations in the area.

As noted in the literature review of Chapter 2, there are many good examples of descriptive views using GIS. All these provide very good reference to conduct this research in the Bay of Fundy. However, it is noticed that most of the site selections and evaluations introduced by Nath et al. (2000) are conduced only based on the natural conditions - physical, chemical, biological etc. Therefore according to the frame proposed by DFO (2003), these evaluations only represent half results, which belong to the left hand side column of Figure 3-1, the natural ecosystem.

In this study, the natural ecosystem is decomposed into (1) Resources, (2) Habitat, and (3) Toxicology, as well as (4) Activities that account for human intervention and socioeconomic functions that act on the natural system. Each component is measured quantitatively by a subgroup of specific items that are members of the four components. In detail, they are:

- Herring Day, Herring Night, Lobster, Scallops and Urchins for Resources;
- Rockweed, Salt Marshes, Current Flow and Bottom Structure for Habitat;
- Chemical A, Chemical B and Chemical C for Toxicology; and
- Herring Weirs, Fish Farms, Lobster Traps, Scallop Drags and Urchin Drags for Activities

Therefore, assuming there exists a geocoded representation of each component, these can be uploaded to the map, and extracted, and the overlapped value evaluation for the selected site obtained. Similarly, comparison of different sites can be ranked and alternative policy options compared.

However, the evaluation of overlapping components and their subcomponents is not the simple superposition of different overlapping layers. It is necessary therefore to consider the interaction between different layers. To simplify the process and to show the backbone of this method, data are limited to: (1) an ID number identifying different components and subcomponents, (2) a unit area Yield value and (3) corresponding Yield for the whole of the overlapping area. For example, Table 3-1 represents one available data table in this study identifying an area of size 54.2 km^2, corresponding to component Resource number 5, having a total yield of 1427.3 value units (based on a unit Yield for Resource 5 of 26.33 value units as specified in the input). The general input data, unit yields of different subcomponents, in this study is summarized as Table 3-2.

Table 3-1 Data table containing 3 columns

IDResources	Yield	Area
5	1427.3	54.2

Table 3-2 Nonzero unit yield values used in this study

Name	YR Herring Day	YR Herring Night	YR Urchins	YH Rockweed	YH Salt Marshes	YT Chemical A	YA Herring Weirs	YA Fish Farms	YA Urchin Drags
Unit Yield	750.0	1511.0	988.0	350.0	551.0	1501.0	1121.0	26.0	249.0

The output data are the combination of different input data tables. It is not convenient to design the output table structure by placing all input data table items (including 5 Resource, 4 Habitat, 3 Toxicology and 5 Activities subcomponents) side-by-side. Rather, by incorporating only those items that are present in the selected area, the output table as in Table 3-3 is constructed. This table of the overlapping results is part of a complete overlap description table and saves all needed information for further analysis in it. The definition of each Item and it valuation are explained further following the table below.

Table 3-3 Extracted information of overlapping layers from the selected area in the output table

(1)				(2)				(3)
ID Resources	ID Habitat	ID Toxicology	ID Activities	Yield Resources	Yield Habitat	Yield Toxicology	Yield Activities	Area
0	0	0	0	0.0	0.0	0.0	0.0	35.9
0	0	0	5	0.0	0.0	0.0	748.9	3.0
0	0	0	1	0.0	0.0	0.0	330.1	0.3
0	1	0	0	0.0	42.0	0.0	0.0	0.1
0	1	0	1	0.0	34.6	0.0	110.8	0.1
5	0	0	0	12669.9	0.0	0.0	0.0	12.8
5	0	0	5	2969.0	0.0	0.0	748.9	3.0
2	0	0	0	8700.4	0.0	0.0	0.0	5.8
2	0	0	5	6.9	0.0	0.0	1.1	0.0
52	0	0	0	4316.6	0.0	0.0	0.0	1.7
52	0	0	5	11.5	0.0	0.0	1.1	0.0
1	0	0	0	9781.9	0.0	0.0	0.0	13.0
1	0	0	5	1202.9	0.0	0.0	399.8	1.6
51	0	0	0	9619.2	0.0	0.0	0.0	5.5
51	0	0	5	2787.8	0.0	0.0	399.8	1.6
21	0	0	0	4228.6	0.0	0.0	0.0	1.9
521	0	0	0	3054.6	0.0	0.0	0.0	0.9

In Table 3-3, Column Definitions are as follows:

(1) IDResources, IDHabitat, IDToxicology and IDActivities represent the indices of Resources, Habitat, Toxicology and Activities respectively;

(2) YieldR, YieldH, YieldT and YieldA represent the corresponding Yields of Resources, Habitat, Toxicology and Activities in the specific overlapping layer of the selected area;

(3) The Area column shows the total area corresponding to the ovelapping layers indicated by each line of the table. The first line in which all IDs are zero represents the total selected area in square kilometres, km^2.

The ID value definitions for Table 3-3 denote the following subcomponents:

1. IDResources:
   - 0 - Not present in the current overlapping area;
   - 1 - Herring resource abundance during Day-time aggregations;
   - 2 - Herring resource abundance during Night-time aggregations;
   - 3 – Lobster resource abundance;
   - 4 – Scallop resource abundance;
   - 5 – Urchin resource abundance.

2. IDHabitat:
   - 0 - Not present in the current overlapping area;
   - 1 – Rockweed habitat present;
   - 2 - Salt Marshes habitat present;
   - 3 - Bottom Structure description, e.g., sandy, gravelly, etc.;
   - 4 - Current Flow description.

3. IDToxicology:
   - 0 - Not present in the current overlapping area;
   - 1 - Chemical A (precise chemical to be identified here);
   - 2 - Chemical B (precise chemical to be identified here);
   - 3 - Chemical C (precise chemical to be identified here).

4. IDActivities:

    0 - Not present in the current overlapping area;

    1 - Herring Weirs present;

    2 - Fish Farms present;

    3 - Lobster Traps present;

    4 - Scallop dragging area;

    5 – Urchin dragging area.

It is noted that when there are two or more than two digital numbers in the same ID columns (1) of Table 3-3, the index cell represents the overlaps of different subcomponents originating from the same component group. For example, in the table above, the second last line 2 of the data table identifies ID Resources = 21 means the overlap between Herring Night ("2") and Herring Day ("1") in the specific overlapping area.

In any specific overlapping area, it must contain at least one data ID unequal to zero from among the subcomponents. In this case, there is no overlap. It is more meaningful if it contains more than one overlapping data since one of the key purposes of this study is to deal with the conflicts among different groups and components. The next question is "how can the Yield values for the designated and defined overlapped areas be calculated?" Clearly, if there is no overlap, the Yield values are already a simple function of the unit Yield values input for each subcomponent. However, if there are any overlapping subcomponents, the situation may become complicated (increasing with the numbers of overlaps) and the need arises to determine strict "overlap ruler" to deal with these cases. The set rules for this problem are provided below:

Rules of layer overlapping:

(1) Definition - When more than one layer occupies the same area (superposition) as another, the two (or more) spaces are said to be overlapping layers;

(2) Yield Determination - Layer overlapping will affect the yields of the overlapped layers. The result may increase or decrease the original component yields. For example, if one layer of a Resources or Habitat subcomponent is overlapped with another Resources or Habitat subcomponent, the effect will be a positive increase on the overall Resource Yield or the Habitat Yield of the selected area; if, on the other hand, the second overlapping subcomponent belongs to Activities, the effect will be negative on the overall Resource Yield or the Habitat Yield of the selected area. For Toxicology, if it is overlapped with any other component layer A, the yield of layer A will decrease by the same yield amount as is produced by the layer A in the overlapped area. The Toxicology layer will increase its yield by the same amount (Note, the higher the yield of a Toxicology layer, the larger the negative effect it will produce);

(3) Average Unit Area Yield - Let area AB represent the overlapped part of layer A and layer B in some selected area; Y(A) and Y(B) represent the corresponding yields and the overlapping effect per unit area can be expressed by the average unit area yield [Y(A) + Y(B)]/2;

(4) Multiple Overlapping Layers - The effect of more than two overlapping layers in the same space is a very challenging problem. In this study, a comparatively simple method is adopted, that is, only pairwise overlapping is considered. For example, a triple overlapping ABC will be considered as a triple overlapping of the areas: AB, AC and BC. Similarly, the yield determination is made based on the impacts by pairs.

These overlapping rules described above are summarized in Table 3-4.

Note to Table 3-4: Plus signs (+) denote that the overlapping effect on yields for the layer indicated at the left hand side is positive; minus signs denote negative yields. Please also note: this is not a symmetric matrix. For example, the overlapping effect of Resources and Activities is negative for Resources, but is positive for Activities.

Table 3-4 Summary of Rules for Overlapping Layers

	Yield Affecting Components			
Yield Affected Components	Resources	Habitat	Toxicology	Activities
Resources	+	+	-	-
Habitat	+	+	-	-
Toxicology	+	+	+	+
Activities	+	+	-	-

In the selected area output table, Table 3-3, the left 4 ID columns record the overlapping situation by subcomponent. The right 4 Yield columns record the corresponding yield by component. For example, if the ID cell in IDResources is not empty (value greater than zero), then the Yield Resources cell must contain a non-zero value. If IDResources=1, then the Yield Resources = 38 denotes that the yield of the Herring Daytime resource is 38 yield units; if instead IDResources=12, then the Yield Resources of 38 means that the summation yield between Herring Day and Herring Night is 38. Only the summation yield or the original yield is presented in this table. All overlapping rules are used to determine the Yield cell values as applied to this table.

In conformity with the overlapping rules, the yields from all 17 subcomponent items (or a vector with 17 dimensions) including overlapped and non-overlapped parts are calculated. This result is considered as the prototype evaluation of the selected site or area and the input of next analysis made by *Expert Choice 2000.*

As pointed out in the previous analysis, the calculated yield impact values for a selected area are only half of the decision support evaluations. That is, these results do not reflect the interpretations of different participants in the problem solving situation. In order to obtain a more complete comprehensive evaluation, the need to combine different participants' ideas is very important. The introduction of multi-criterion decision making methods and the Analytic Hierarchy Process (AHP), discussed further below, are adopted to take this step into account.

3.3 Multicriteria Decision Making and AHP

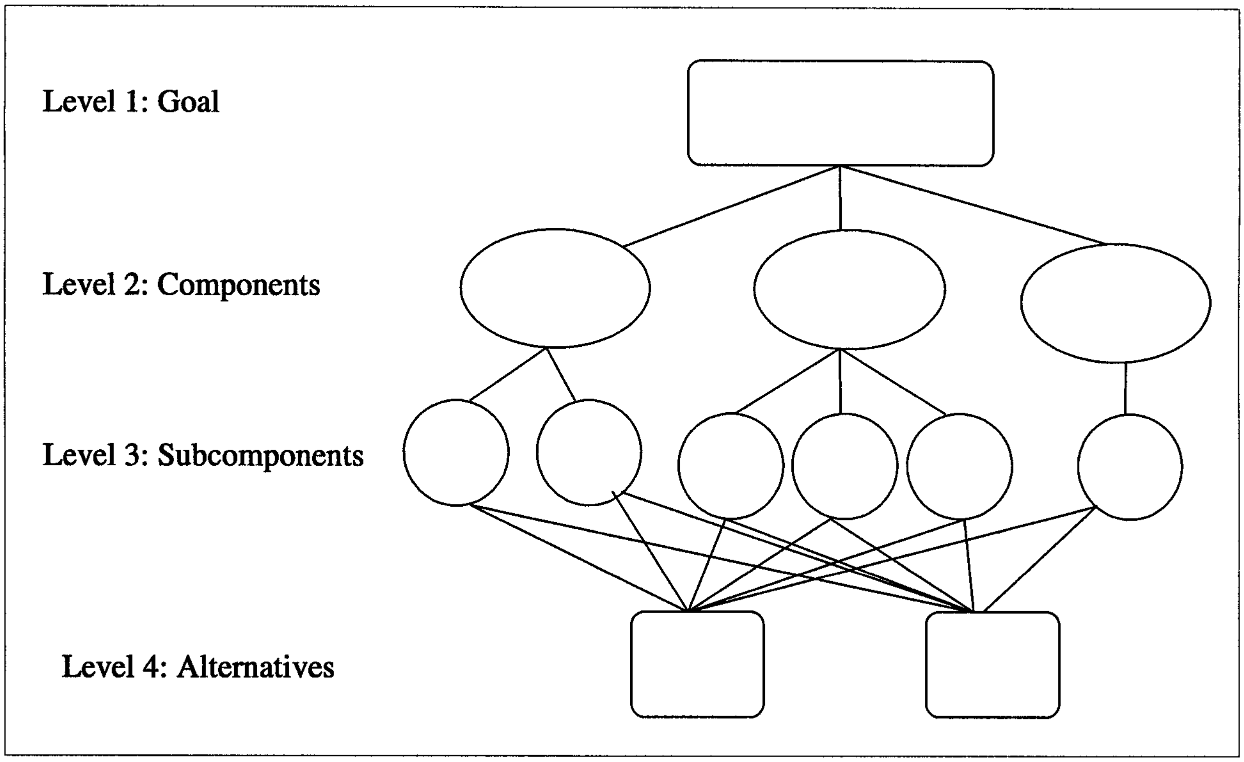


Figure 3-3 The Analytic Hierarchy Process: Hierarchical Problem Formulation Structure

The Analytic Hierarchy Process (AHP) was developed by Thomas Saaty (1980). The method provides an effective and logical way for problem solvers to structure decisions in a complex, multicriteria setting using a hierarchical problem structure. AHP contains several necessary concepts and techniques such as hierarchical structure, pairwise comparisons and an eigenvector method for calculating weights and determining consistency in inputs, etc. With the appearance of the AHP computer implementation software, *Expert Choice* (Expert Choice 1983), the number and diversity of AHP applications have grown rapidly. The International Society of the Analytic Hierarchy Process held its first meeting "International Symposium on the Analytic Hierarchy Process" in 1988, in Tianjin, China (Forman et al. 2004).

AHP includes special concepts such as pairwise comparisons, and trade-off valuations. The first step of applying AHP is to build a hierarchy model that includes specifying the Goal, determining the Components, Subcomponents, as well as the decision alternatives (Figure 3-3).

The following section combines the topic of coastal aquaculture and the site selection and evaluation problem to discuss the basic concepts of AHP and to illustrate this application of the AHP software - *Expert Choice 2000.*

3.3.1 Pairwise Comparison and *Expert Choice 2000*

Pairwise comparison is an effective way to accept trade-off data from decision makers and then to rank multiple factors through the binary input comparisons of the factors. By pairwise comparison, decision makers collect objective as well as subjective trade-off valuations about the structured problem and convert them to a numerical ranking and weighting of the problem components. The purpose here is to provide decision support for decision makers. Specifically, different and generally selected marine areas are evaluated based on each area's inventory of components and on the different considerations and valuations of the participant. For example, three typical questions are:

(1) What is the estimated yield value for a specific area?
(2) What is the difference between this stated yield value and an ideal yield value?
(3) What is the ranking of different selected areas compared to each other and to an ideal area?

In order to answer these kinds of questions, the trade-offs for the structured criteria for each of the participants in the aquaculture problem are estimated.

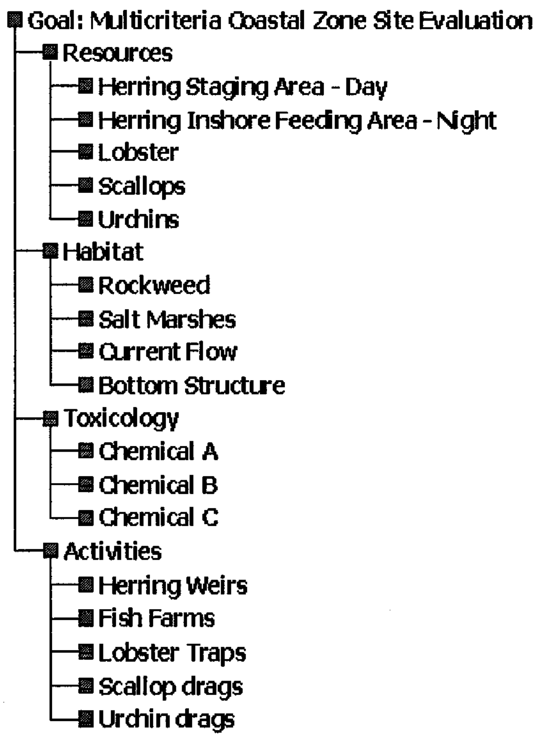


Figure 3-4 The hierarchical model of the 17 subcomponents in the Grand Manan study (Source: Output of problem formulation from *Expert Choice 2000*)

According to the previous analysis, the 17 subcomponent items which belong to the 4 different component groups are used to construct a hierarchical model as provided in Figure 3-4 below.

As denoted in Figure 3-4 above the following items are explicitly identified:

(1) Goal: The goal is defined as the "Multicriteria Coastal Zone Site Evaluation".

(2) Components: Representation of the major components of the aquaculture system around Grand Manan, namely, Resources, Habitat, Toxicology, and Activities.

(3) Sub-components: Detail of the major components, namely, the specific items:

- Resources: Herring Staging Area - Day, Herring Inshore Feeding Area - Night, Lobster, Scallops, and Urchins;
- Habitats: Rockweed, SaltMarshes, CurrentFlow, BottomStructure;
- Toxicology subcomponents: ChemicalA, ChemicalB, ChemicalC ; and
- Activities: HerringWeirs, FishFarms, LobsterTraps, ScallopDrags, ScallopDrags, UrchinDrags .

(4) Alternatives: The decision alternatives are expressed as the selected marine areas for evaluation, comparison and ranking.

For a specific selected area, the related values of the lowest levels in the hierarchy (the subcomponent yield valuations) are determined by GIS. That is, a yield vector along the 17 dimension subcomponent yields (for Resources: HerringDay, HerringNight, Lobster, Scallops, Urchins; Habitats: Rockweed, SaltMarshes, CurrentFlow, BottomStructure; Toxicology: ChemicalA, ChemicalB, ChemicalC; and Activities: HerringWeirs, FishFarms, LobsterTraps, ScallopDrags, ScallopDrags, and UrchinDrags). Clearly, based only on the values of the 17 yields for each of a set of selected areas, the multidimensional ranking of the selected areas could only be done if the subcomponents and the components themselves were assigned a priority or weight. The structured AHP process and the use of the pairwise trade-offs are used to assist in the determination of priorities for each decision maker. The following 5 basic processes are conducted to determine the weights of the different levels in the decision hierarchy.

(1) Set the scale of judgment

In order to describe the binary comparison trade-offs, the scale to represent these trade-offs needs to be defined. Normally, 3, 5 or 9 point discrete scales are adopted. In this analysis a 9 point scale is applied to all pairwise comparisons. The meaning of the scale items is described in Table 3-5.

Table 3-5 Judgment Preference Scale for Paired Comparisons

Numerical	Verbal
1	Equal
2	Equal to Moderate
3	Moderate
4	Moderate to Strong
5	Strong
6	Strong to Very Strong
7	Very Strong
8	Very Strong to Extreme
9	Extreme

Note: The verbal scales denote the relative importance of item 1 over item 2 with respect to the Goal of the problem; a similar scale exists for comparing the relative importance of item 2 over item 1.

(2) Compare all factors pairwise in level 2

By posing the pairwise comparison questions, the judgments and valuations made by different decision making groups are obtained for each comparison of the major components. For example, the question is put to a decision maker such as: "Resources and Habitat, which of these is more important to achieving the Goal of highest value of the marine site, and to what extent?" A possible answer is: "Resources are equal or moderately less important than Habitats." Or, "Habitats are equal or moderately more important than Resources to achieving the overall Goal." This gives us a numerical judgment of "2" for Habitat over Resources in this single binary comparison (from Table 3-5). In the same way, all pairwise comparisons of the components in this layer are determined from the decision makers' feedback. Accumulating the full state of these judgments into a table (Table 3-6 below) for the four major components of this problem yields the relative importance of each component. The above statement "Habitat is equal to moderately more important towards achieving the Goal than Resources" is denoted by the "2" in the cell (2, 3) corresponding to row Habitat and column Resources. Inversely, Resources are equal to moderately less important as Habitat and the value in the transposed cell (3, 2) corresponding to row Resources and column Habitat is therefore 1/2. Obviously, when a factor is compared with itself, the value is 1, "Equal". These characteristics make the table a special square table in which all diagonal elements are 1; and, the products of any two transposed cells around the diagonal line are also 1. Furthermore, cells above or below the diagonal, total are (N-1+1)(N-1)/2 cells for an N factor table, represent required pairwise comparison valuations to be requested from decision makers.

Table 3-6 Comparison table of the relative importance of rowwise components to columnwise components with respect to the Goal of achieving greatest value for a selected marine area

	Resources	Habitat	Toxicology	Activities
Resources	1	1/2	1/5	2
Habitat	2	1	1	2
Toxicology	5	1	1	3
Activities	1/2	1/2	1/3	1

Note: The table above corresponds to the component pairwise comparisons attributed to Local Communities' decision makers as one of several decision making groups (see also below).

(3) Establish priority by computing eigenvectors

Suppose the pairwise comparison matrix written in general form is:

$$A = \begin{bmatrix} w1/w1 & w1/w2 & \cdots & w1/wn \\ w2/w1 & w2/w2 & \cdots & w2/wn \\ \cdots & \cdots & \cdots & \cdots \\ wn/w1 & wn/w2 & \cdots & wn/wn \end{bmatrix} \quad (3\text{-}1)$$

The objective is to calculate the vector $w^{T} = [w1, w2, w3, \cdots, wn]$ of relative weights of the components from this pairwise comparison data.The vector w^T denotes the transposed vector w. This is considered in AHP as a problem of determining the eigenvalues and eigenvectors of matrix A. That is, w^T is determined by definition of an eigenvector, such that:

$$A \cdot w = n \cdot w \tag{3-2}$$

This equation can also be expressed in the form

$$(A - n \cdot I) \cdot w = 0 \tag{3-3}$$

where I is the identity matrix of order n, the number of components (rows or columns) in the problem.

In order to make $w \neq 0$, n must be the eigenvalues of matrix A and then w becomes the eigenvector of matrix A. Furthermore, since each row of matrix A is a constant multiple of the first row, the rank of the matrix A must be one. Therefore the eigenvalues of matrix A, $\lambda_i \ (i = 1, 2, \cdots, n)$, only contain one non-zero value. In addition, because the trace of the matrix A, i.e., the sum of the elements on the main diagonal, is equal to the sum of all eigenvalues of the matrix A, it is clear that

$$\lambda_i = 0 \text{ and } \lambda_{\max} = n \quad (\lambda_i \neq \lambda_{\max}) \tag{3-4}$$

Finally, the non-trivial eigenvector corresponds to the maximum eigenvalue $\lambda_{\max}$. By normalizing this eigenvector the weight vector w, is obtained.

In fact, $\lambda_{\max}$ will be greater than or equal to n and the other λ values will be close to zero. It is reasonable however, to allow some measurable inconsistency from the pairwise comparison data collection. Saaty (1980) defined a consistency index as

$$C.I. = (\lambda_{\max} - n)/(n-1) \quad (3\text{-}5)$$

The closer $C.I.$ is to 0, the more consistent the judgments. Saaty (1980) suggested $C.I.$ should be smaller than 0.1 as a “rule of thumb”.

In the current research, based on the pairwise comparison table (as in Table 3-6), which shows the relative importance of each pair of component factors. It is easy to obtain the matrix eigenvector and the resulting component weights. For Table 3-6, the non-trivial scaled eigenvector or the priority vector is (0.147, 0.302, 0.435, 0.116) corresponding to the overall importance ranking of each of the components.

Obviously, the important rank in this case is as Toxicology is more important than Habitat is more important than Resources is more important than Activities.

(4) Compare all factors pairwise in level 3 and establish their priority vectors

Now move to the level 3 of the hierarchical model (Figure 3-8) and do pairwise comparison for each pair of subcomponent factors. The factors to be compared belong to the component groups:

- Resources: (Herring staging area –Day, Herring inshore feeding area – Night, Lobster, Scallops, Urchins);
- Habitat: (Rockweed, Salt marshes, Current flow and Bottom structure);
- Toxicology: (Chemical A, Chemical B and Chemical C);
- Activities: (Herring weirs, Fish farms, Lobster traps, Scallop drags and Urchin drags).

Using the same method taken in step 2, construct 4 tables for Resources, Habitat, Toxicology and Activities respectively and then fill the corresponding cells by paired comparison. The applied method is exactly the same one of applied in step 3. The results are shown below. Note that all tables correspond to the component pairwise comparisons attributed to Local Communities’ decision makers as one of several decision making groups.

(1) Resources

Table 3-7 Comparison table of the relative importance of rowwise Resource subcomponents to columnwise Resource subcomponents with respect to the Goal of achieving greatest value for a selected marine area

Resources	Herring Day	Herring Night	Lobster	Scallops	Urchins
Herring Day	1	1	1	1	1
Herring Night	1	1	1	1	1
Lobster	1	1	1	1	1
Scallops	1	1	1	1	1
Urchins	1	1	1	1	1

The weight vector for this table of all "equal" valuations is also "equal" to each of the subcomponents, e.g., $w = (1/5, 1/5, 1/5, 1/5, 1/5) = (0.20, 0.20, 0.20, 0.20, 0.20)$. That is, for Resources subcomponents in this valuation, the rankings of Herring Staging Area – Day, Herring Inshore Feeding Area – Night, Lobster, Scallops and Urchins are all the same at 0.20.

(2) Habitat

Table 3-8 Comparison table of the relative importance of rowwise Habitat subcomponents to columnwise Habitat subcomponents with respect to the Goal of achieving greatest value for a selected marine area

Habitat	Rockweed	Salt Marshes	Current Flow	Bottom Structure
Rockweed	1	1/2	2	4
Salt Marshes	2	1	3	5
Current Flow	1/2	1/3	1	1
Bottom Structure	1/4	1/5	1	1

The priority vector for the Habitat subcomponents is (0.292, 0.479, 0.132, 0.098) and the ranking is as Salt Marshes is more important than Rockweed is more important than Current Flow is more important than Bottom Structure.

(3) Toxicology

Table 3-9 Comparison table of the relative importance of rowwise Toxicology subcomponents to columnwise Toxicology subcomponents with respect to the Goal of achieving greatest value for a selected marine area

Toxicology	Chemical A	Chemical B	Chemical C
Chemical A	1	4	6
Chemical B	1/4	1	3
Chemical C	1/6	1/3	1

The priority vector for the Toxicology subcomponents is (0.691, 0.218, 0.091) or Chemical A is more important than Chemical B is more important than Chemical C.

(4) Activities

Table 3-10 Comparison table of the relative importance of rowwise Activities subcomponents to columnwise Activities subcomponents with respect to the Goal of achieving greatest value for a selected marine area

Activities	Herring Weirs	Fish Farms	Lobster Traps	Scallop drags	Urchin drags
Herring Weirs	1	1	1/2	1/2	1
Fish Farms	1	1	1/2	1/2	1
Lobster Traps	2	2	1	1	3
Scallop Drags	2	2	1	1	2
Urchin Drags	1	1	1/3	1/2	1

The priority vector for the Activities subcomponents is (0.141, 0.141, 0.307, 0.281, 0.130) and the ranking is Lobster Traps is more important than Scallop Drags is more important than Herring Weirs is equally as important as Fish Farms is more important than Urchin Drags.

(5) Assign the weights for the hierarchical model

From the previous steps, the priority vectors for level 2 and level 3 are assigned weights to each level factor. The resulting scaled weights for the problem illustrated above are illustrated in Figure 3-5 below.

According to *Expert Choice 2000*, the local priority represents the percentage of the parent node's priority that is inherited by the child. The local priorities of the children of a node also sum to one; Global priority is the priority of each node relative to the Goal. The global priorities of a node represent the portion of the parent's priority inherited by the child. The global priorities of all the children equal the parent's global priority. The global priority of a child equals the local priority of the child times the global priority of the parent.

The 5 steps introduced above represent the process of using pairwise comparison to determine valuations and weights for the structured problem.

Using the software package *Expert Choice 2000*, all 5 steps can be finished automatically via the input module for the paired comparison results of the table cells. Similarly, all results can be output by sets of internal figures and reports. In the following section, the AHP results are illustrated for the different groups that participate in the aquaculture decision making process.

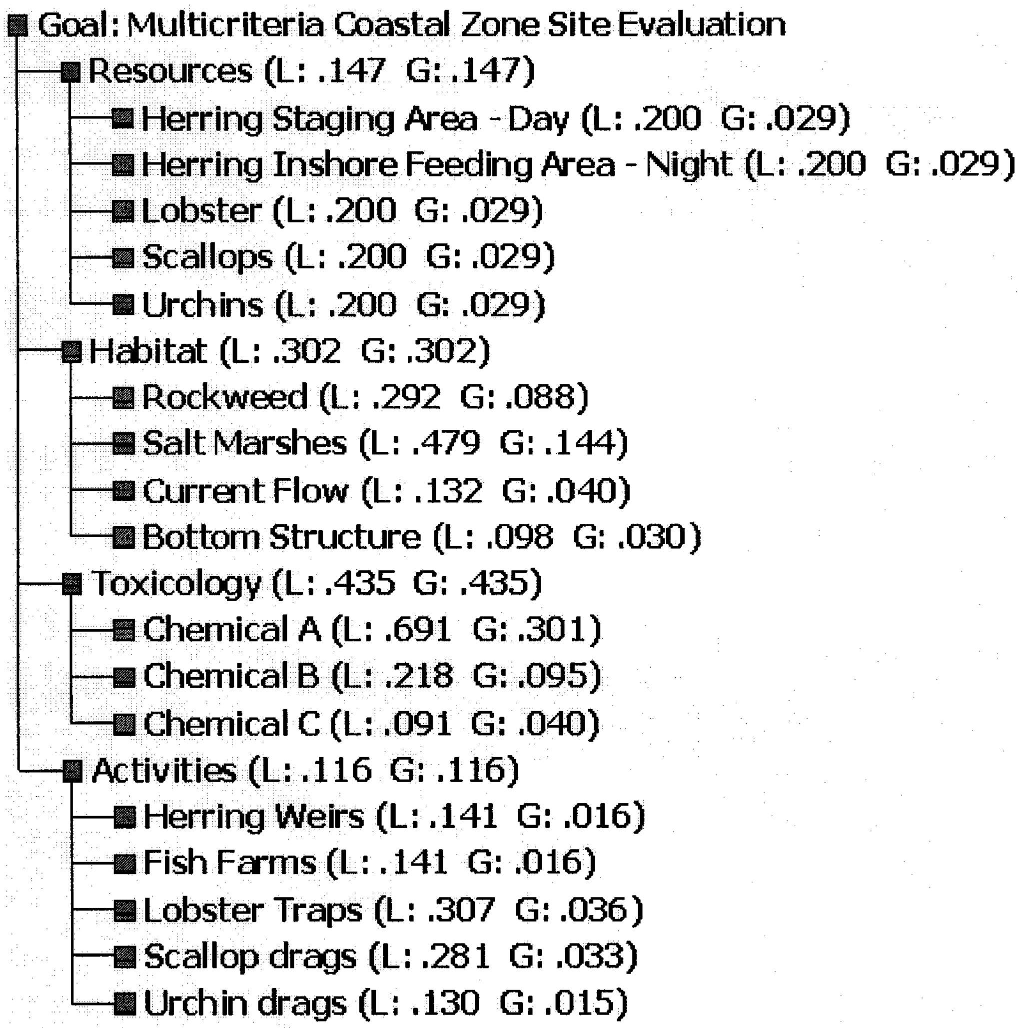


Figure 3-5 The hierarchical model for the aquaculture problem, where L is the local priority and G is the global priority; weight values are attributed to the Local Communities group

3.3.2 Information integration of different social organizations

Assigning weights from pairwise comparisons for each layer is a task of relative subjectivity for decision makers. Different interpretations, methods and points of view may result in quite different ranking results for the same selected areas by different participants. In the study, the participant organizations are summarized into five representative groups. They are:

(1) Local Communities

(2) Federal Scientists

(3) Industrial organizations

(4) Non Governmental Organizations

(5) Provincial Governments

These groups are introduced together with their different views through their attributed responses to pairwise comparisons and resulting weights for the layers of the hierarchical model of Figure 3.9. Therefore, based on these different view points the same selected area is ranked differently and with quite different scores by the different participant groups. When decision makers in a responsible, governance setting obtain this kind of explicit information on ranking, it is very helpful for them all to define relevant policies based on the selection of marine areas.

In this thesis, no reconciliation of intra or inter groups' differences are considered. It just summarizes different groups' tendency for different components and showed attributed results to the decision makers to illustrate these differences. While the issue of reconciliation is an important one, it is not the focus of this thesis and is not discussed specifically here.

In summary, the useful methods and techniques described for this study have been presented. Using MapInfo, the various data can be integrated onto a map and the overlapped data in any specific area can be extracted easily. Next, using the multicriteria AHP methods, different attitudes can be summarized comparatively. In the next section procedures for streamlining the integration of this overall process are described for the coastal aquaculture problem.

3.4 Integration of VB.Net, MapInfo and *Expert Choice 2000* for DSS

This section describes the methodology for customizing interfaces using VB.NET to combine MapInfo and AHP to work together for the specific application of the coastal aquaculture problem. This will simplify the necessary modelling operations described above and make the whole process easier to apply.

3.4.1 Integrating VB.Net and MapInfo

MapInfo provides very good support for Object Linking and Embedding (OLE). It allows users and developers to embed a MapInfo map directly into an OLE container application. That means if a VB.Net application can be created that can integrate a MapInfo Map window directly into it, while permitting most of the MapInfo functionality to be programmed and controlled for the specifics of the application in VB.Net (MapInfo 2002c). In that way, the appearance of the Integrated Mapping application via a friendly interface which customizes the whole process from displaying, selecting and extracting data and results as needed.

The basic theory of integrated mapping is as follows:

(1) Issuing a statement within the VB.NET interface program to launch MapInfo in the background.

MapInfo is launched by calling the CreateObject( ) function. MapInfo launches silently in the background without displaying a splash screen;

(2) Manipulating MapInfo by MapBasic

MapBasic is a software package that lets users and developers customize and automate the MapInfo desktop mapping software (MapInfo, 2002c). Strings are constructed that represent MapBasic statements using OLE Automation to send the strings to MapInfo. MapInfo then executes the statements as if the user had typed the statements into the MapBasic command window.

(3) Keeping Data format changeless

Integrating MapInfo's windows into another application does not give MapInfo access to the other application's data. Before data can be dealt with in a MapInfo window, it must be stored in a MapInfo table.

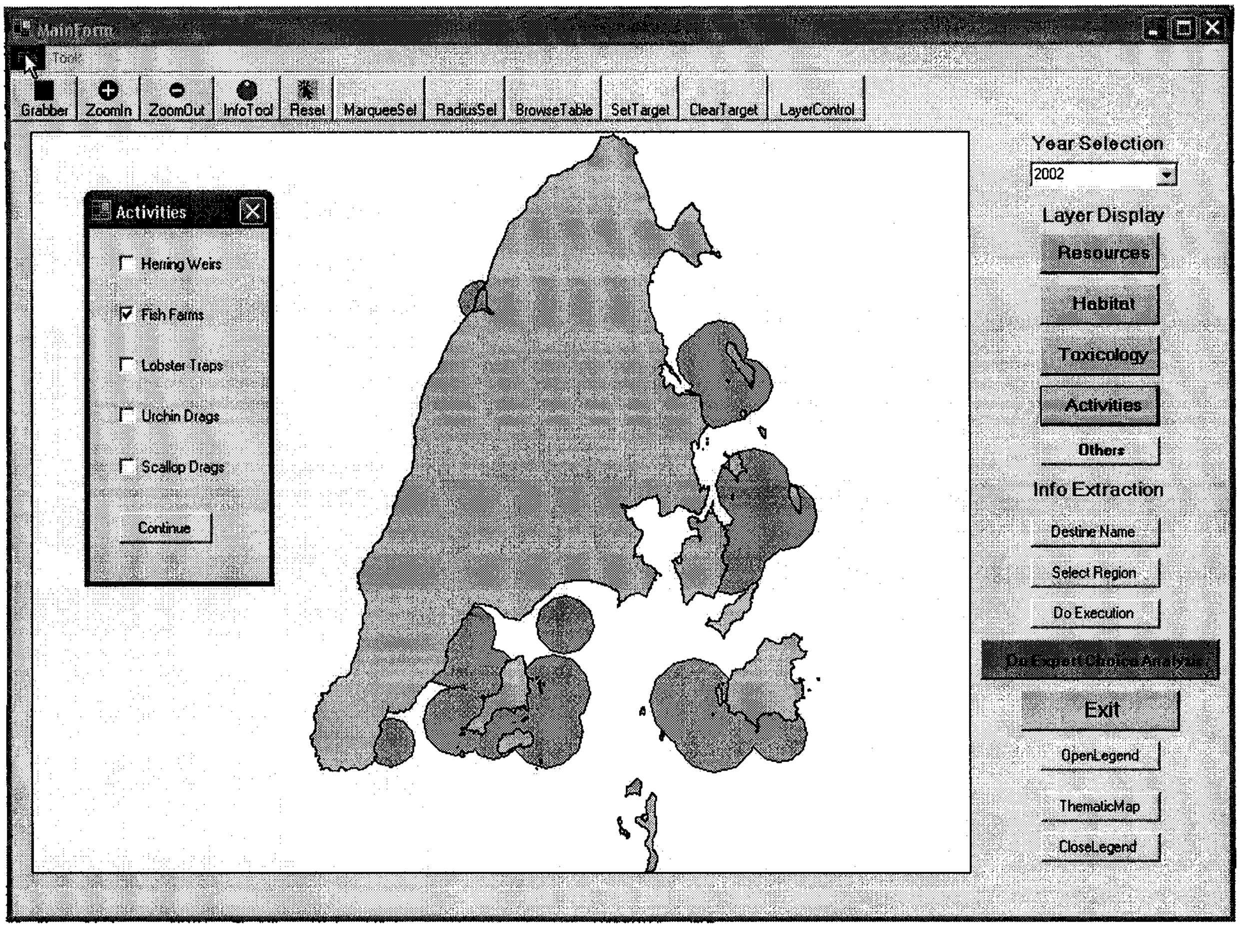


Figure 3-6 Map of Grand Manan Island and VB.NET Customized main interface for the coastal aquaculture analysis

Using OLE, a customized interface, Figure 3-6, is constructed by VB.Net. This interface combines standard MapInfo's interface (MapInfo 2002a) and Liu's interface design (Liu 2001) with a map window and a right-side list of specialized tools. It also aims to integrate and extract data for the AHP analysis of the problem. Along the top of Figure 3-6, the dropdown menu "File" and "Tools" as well as the tool bar including GIS tool buttons for "Grabber", "ZoomIn", "ZoomOut" etc., imitate MapInfo's structure. On the right hand side, all buttons in the interface are designed to simplify the GIS operations. Their functions are briefly explained as follows:

(1) Year Selection: This dropdown list is used to select a specific year's data. In this study, the database contains information from 1998 to 2002, and the five years of data coverage are

applicable to most used layers.

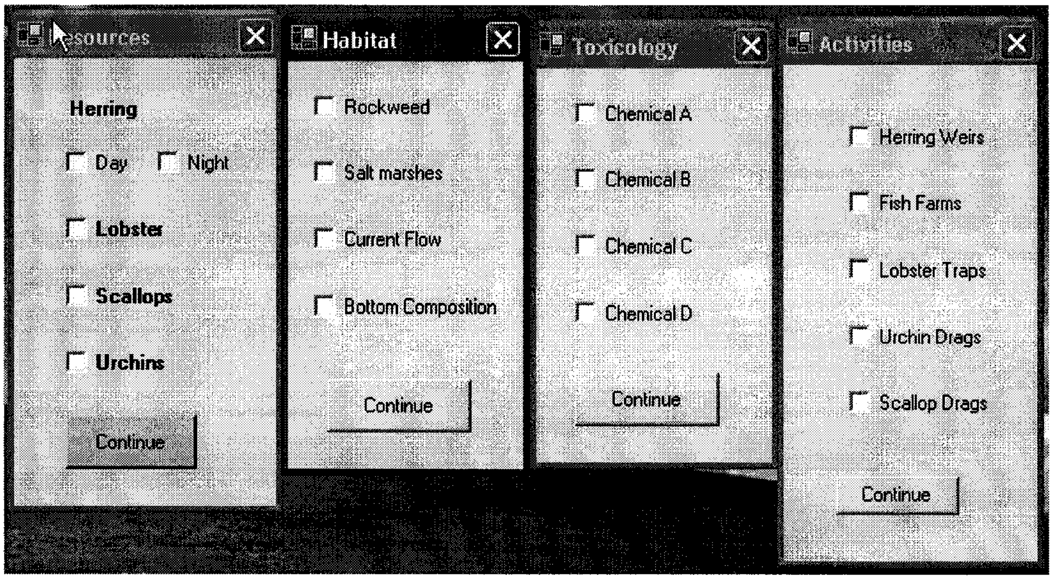


Figure 3-7 Full slate of Layer Control options in the Pop-up window; map overlays are triggered by clicking the corresponding buttons on this interface

(2) Layer Display Section: These buttons are used to simplify the process of uploading different layers to the map. The four buttons of Resources, Habitat, Toxicology and Activities correspond to the 4 component groups that are considered for the Grand Manan problem. Clicking one of these buttons, causes a window to pop up that asks the user to specify which components or layers to be added to the map layer. Figure 3-6 shows the pop-up window options for the Activities component button where Fish Farms layer is checked and the results shown in the map window (as circular buffered areas around Grand Manan). Figure 3-7 shows the complete selection options of the 17 subcomponents as pop up windows. In addition, the "Other" button is used to upload some special layers not included in the layer lists of the previous 4 groups including those layers produced by the last operation or newly obtained data layers from additional data sources that may arise. This button provides the possibility to extend the on deck list of available layers.

(3) Information Extraction: This function contains 3 buttons which let users: (1) Designate Name for the identification of files for extracted map information; (2) Select Region that enables the user to use the mapping tools to define a selected marine area to do extraction; and (3) Do Execution by extracting the selected data and saving the final results in the designated file names for further analysis in *Expert Choice 2000.*

(4) Do Expert Choice Analysis: This button is the result of integrating the VB.Net and *Expert Choice 2000* analysis. Clicking this button opens *Expert Choice 2000* and moves the user to do the relevant AHP for the selected group of participants. Figure 3-8 shows the pop- up window by clicking this button. It asks the user to determine which model will be opened by *Expert Choice 2000.*

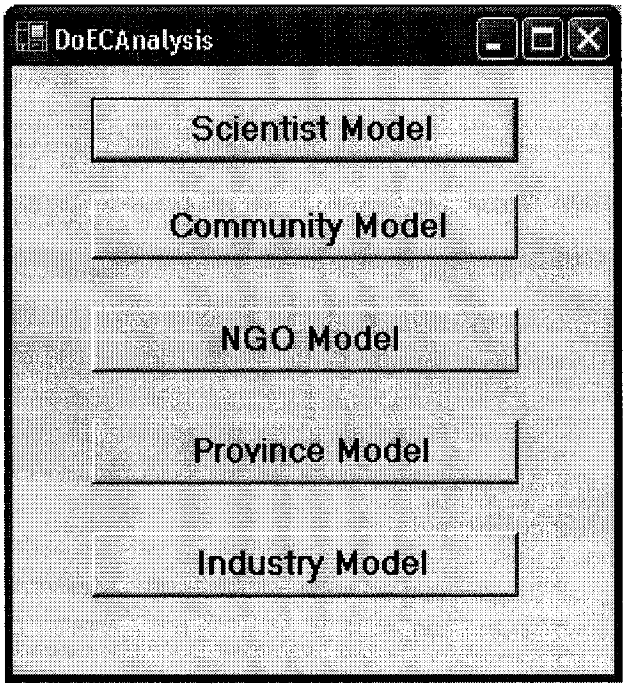


Figure 3-8 Control Pop-Up Window for the activation of different models for use in opening *Expert Choice 2000*

(5) Routine buttons: the Exit option (below the button "Do Expert Choice Analysis"), is used to close the application; the other three buttons of OpenLegend, ThematicMap and CloseLegend are the similar to the functions of the standard MapInfo model.

The above explanation demonstrates that model approaches to integrate successfully the VB.Net and MapInfo tools.

3.4.2 Integrating VB.Net and *Expert Choice 2000*

For *Expert Choice 2000*, the situation is quite different from MapInfo. Since *Expert Choice 2000* does not support OLE methods, integrating it with VB.Net is difficult.

However, it is noticed that *Expert Choice 2000*, like other window applications, contains menu commands. For example, to open an *Expert Choice 2000* file you may use the mouse to click the menu File, and then click Open (Figure 3-9). The underlines of the "File" and "Open" commands actually provide the keystroke method of accessing menu commands: that is, by typing "Alt + F" and then "O". Now, sending keystrokes from one program to another program instead of directly clicking the keyboard can be done. Thus, it is possible to control the menu options of *Expert Choice 2000* using VB.Net.

VB.Net provides an "Interaction module" which contains procedures used to interact with objects, applications, and systems. By this module, *Expert Choice 2000* can be activated. In addition, applying VB.Net's "SendKeys Class" which provides methods for sending keystrokes to an application, most menu commands of *Expert Choice 2000* can be controlled within the VB.NET program. Figure 3-8, the pop-up menu in VB.NET for execution of *Expert Choice 2000*, is actually a control panel which determines which keystrokes will be sent to *Expert Choice 2000*. For example, if the button "NGO Model" is clicked, then *Expert Choice 2000* will be activated and the AHP model specific to the NGO decision makers will be uploaded.

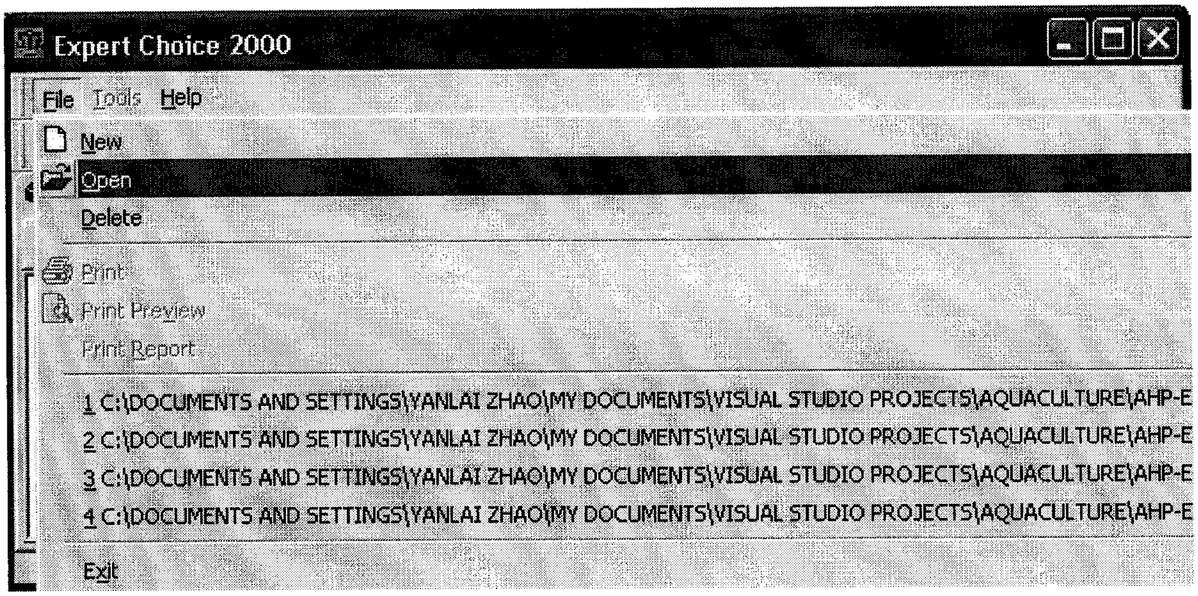


Figure 3-9 *Expert Choice 2000* window for Open a file menu commands

Some parts like the input of *Expert Choice 2000* Data Grid windows are difficult to control directly by keystroke. Fortunately, *Expert Choice 2000* allows data input by File or Windows Clipboard. This means that contents of the Data Grid that are prepared by another program (e.g., Excel) and saved to a file or the Windows Clipboard, then *Expert Choice 2000* will accept this Data Grid input by the menu command "Paste All from File" or "Paste All from Clipboard".

In this study, the GIS output is written to the Windows Clipboard from Microsoft Excel and then pasted to the contents of the appropriate Data Grid at the opening of the selected *Expert Choice 2000* model. Here Excel is used as an intermediary tool; it is optional and may be either open or not open while these commands are issued in the running process.

3.4.3 Integrated panorama and DSS framework

In this thesis, VB.Net, MapInfo, *Expert Choice 2000* and Microsoft Excel are combined to deal with the coastal aquaculture problems. The integrated outline is described in the illustration of the elements in Figure 3-10 representing the operations of (1) the VB.Net code to manipulate

MapInfo; (2) the MapInfo data to produce the GIS output sent to the Excel spreadsheet; (3) the activation of *Expert Choice 2000* and the automatic upload of a prepared AHP model for the key participants (Community Model, Scientist Model, NGO Model, Industry Model or Province Model); (4) the activation to send the selected GIS output to the Windows Clipboard through Microsoft Excel (either Excel is open or close) and then pasting the data from Excel to the Data Grid of the opened *Expert Choice 2000* model.

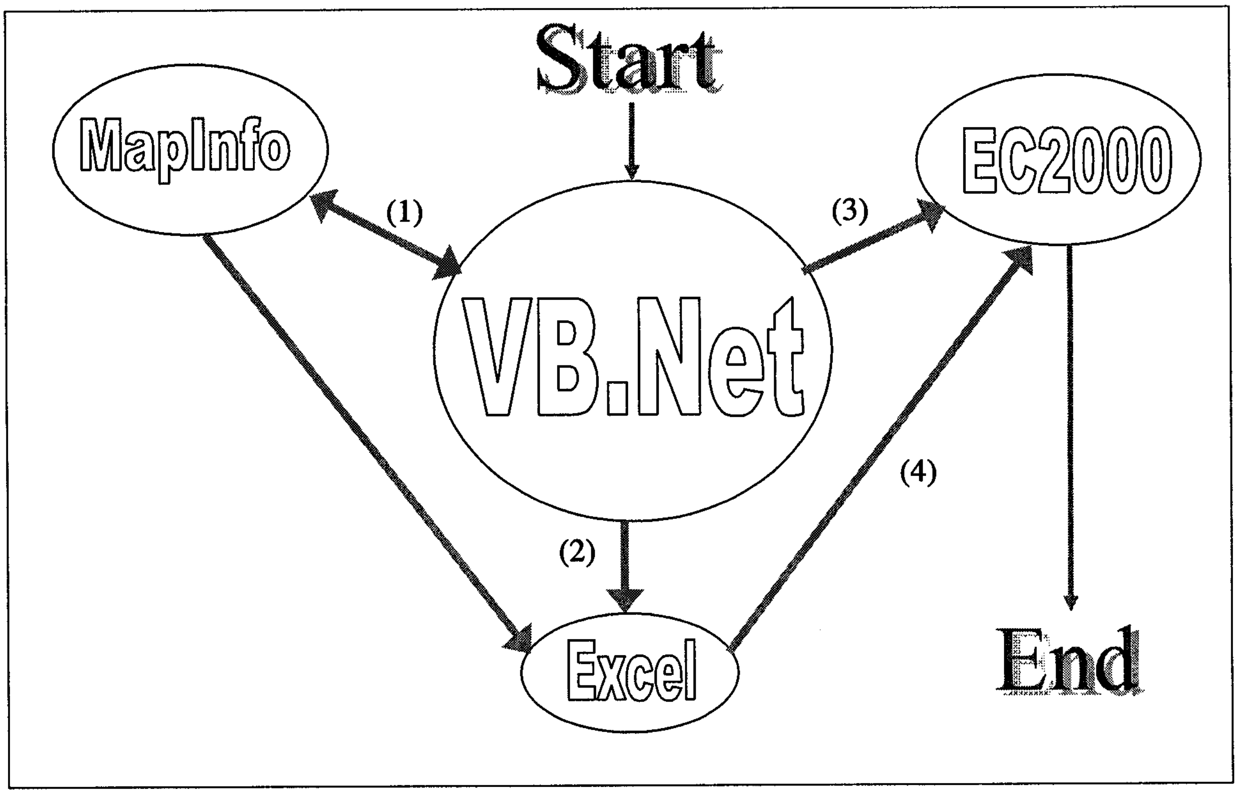


Figure 3-10 Integrated software applications where the arrows show the direction of data flow and the numbered functions described above

Table 3-11 shows the main program work to build the DSS. The complete process of using the developed DSS to coastal aquaculture is summarized in the flow chart of Figure 3-11 below.

Table 3-11 Employed tools and the program contributions to build the DSS

Employed Software	**Related Theory or Computer Language**	**Some Functions**	**Program Contributions to Build the DSS**
Microsoft.Net	VB.Net	Code Applications	Write a specific application by VB.Net
MapInfo	MapBasic	Data Input, Store, Display and Operation	Embed some MapInfo's functions
EC2000	AHP	Priority Determination	Connect *EC2000* to the application

Software engineering is considered as "The application of a systematic, disciplined, quantifiable approach to development, operation, and maintenance of software; that is, the application of engineering to software" (IEEE Std 610, 1990). The development of this application belongs to a small software engineering project. Therefore, principles for software development (Hooker, 1996) are also applicable here. In the developing process, those basic principles such as "to provide value to its users", "to be open to the future", "all design should be as simple as possible" etc. are always carried through all decisions.

Using the developed application, detailed analyses of the coastal aquaculture site selection and evaluation process can be carried out for any specific area around Grand Manan Island. The output results will be judged by different stakeholders and formed various representative ideas. Finally, these ideas will be presented to the decision makers to aid them to make decisions. The whole process of DSS is actually an integration of GIS and AHP.

The following chapter describes the analyses and experimental utilization of the designed DSS.

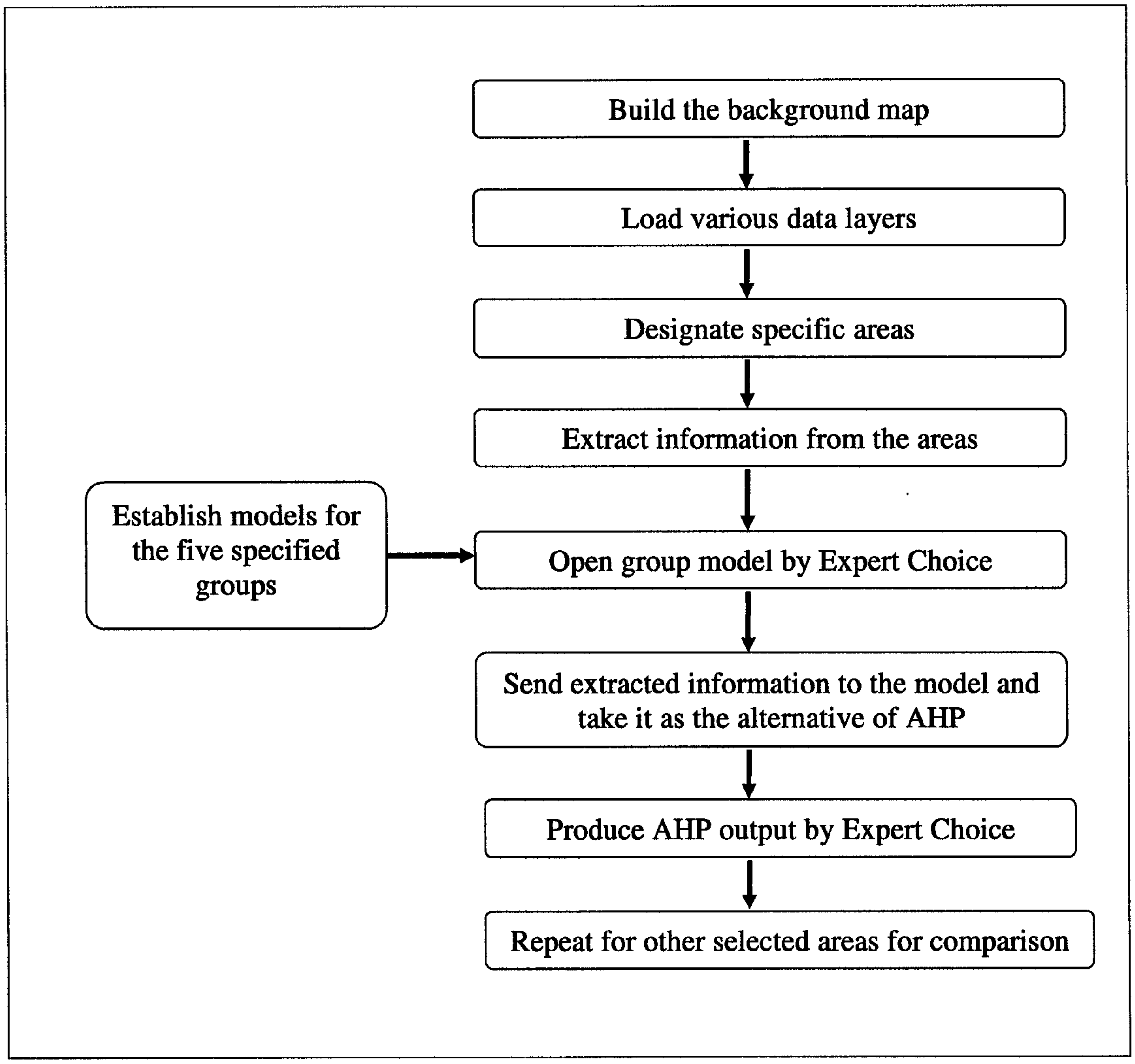


Figure 3-11 Flow Chart of the integrated analysis process

4 ANALYSIS OF RESULTS

The purpose of this research is to provide an effective integration of information and to provide decision making support that recognizes the various participants in the governance process of this situation. Taking Grand Manan Island as the specific study area, the framework of the process described in the methodology of Chapter 3 is applied in the following sections to the specific case.

4.1 The outline of Grand Manan Island Coastal Aquaculture

Grand Manan is about 35km off the south coast of New Brunswick in the Bay of Fundy (Figure 4-1). "The rich waters are home to an abundant variety of marine life that has kept island fisheries thriving for generations" (Government of New Brunswick 2004). The small relative area and its somewhat isolated population (about 3000 islanders) make this study that of a unique area.

4.1.1 Issues and questions

As previously presented above, the key participants in the Grand Manan Island aquaculture decision making process are described in this study by 5 participating groups. These groups have quite different viewpoints about the future directions for developing the marine areas. While it is reasonable to believe that most conflicts among participants arise from their discrepant viewpoints, these discrepancies are generally verbal and not quantified nor clarified. The procedures outlined in this thesis permit an explicit presentation of each group's views about the same problem and thereby provide the means to compare these views quantitatively for benefit in further negotiations about the problem. The adoption of AHP, using *Expert Choice 2000* to make these conflicts more concrete and quantitative are illustrated in the actual examples below.

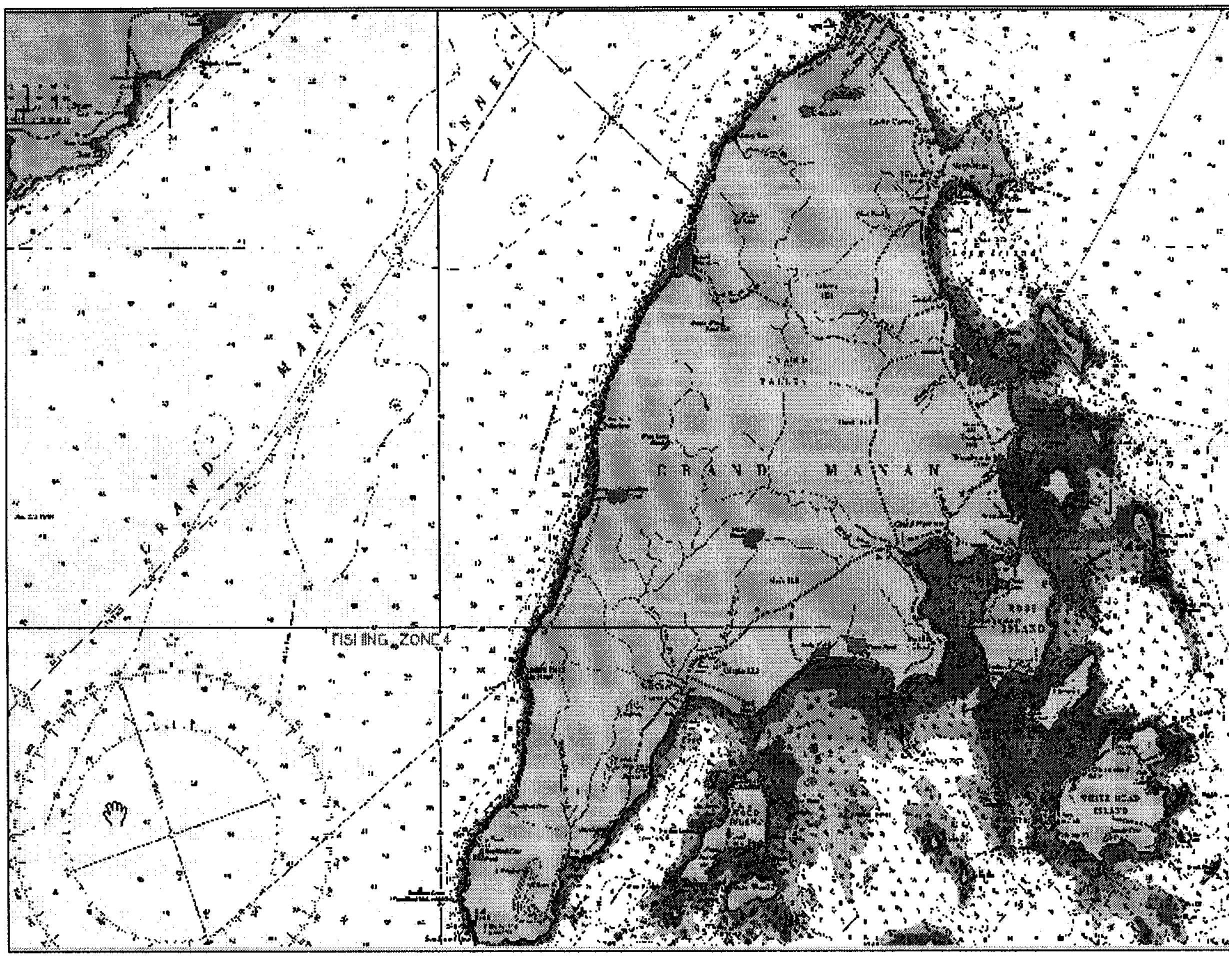


Figure 4-1 Grand Manan Island, 35km off the south coast of New Brunswick in the Bay of Fundy

4.1.2 Data

Data are obtained from the St. Andrews Biological Station in St. Andrews, New Brunswick. The Biological Station is situated on Passamaquoddy Bay, an inlet of the Bay of Fundy, not far from Grand Manan Island. The Biological Station is part of the federal Department of Fisheries and Oceans and is home to federal fisheries scientists who participate in the monitoring and analyses of aquaculture in the local area. This work is carried out in partnership with their colleagues in the Province of New Brunswick that has licensing authority for the provincially governed aquaculture industry. However, the use of federal coastal waters by this industry means that aquaculture is also under the auspices of the federal government through the *Fisheries Act of Canada*. The following sections describe the Grand Manan Island data in maps and tables and provide insight into the interpretations and evaluations of the selected areas.

(1) Coastal line and contour line

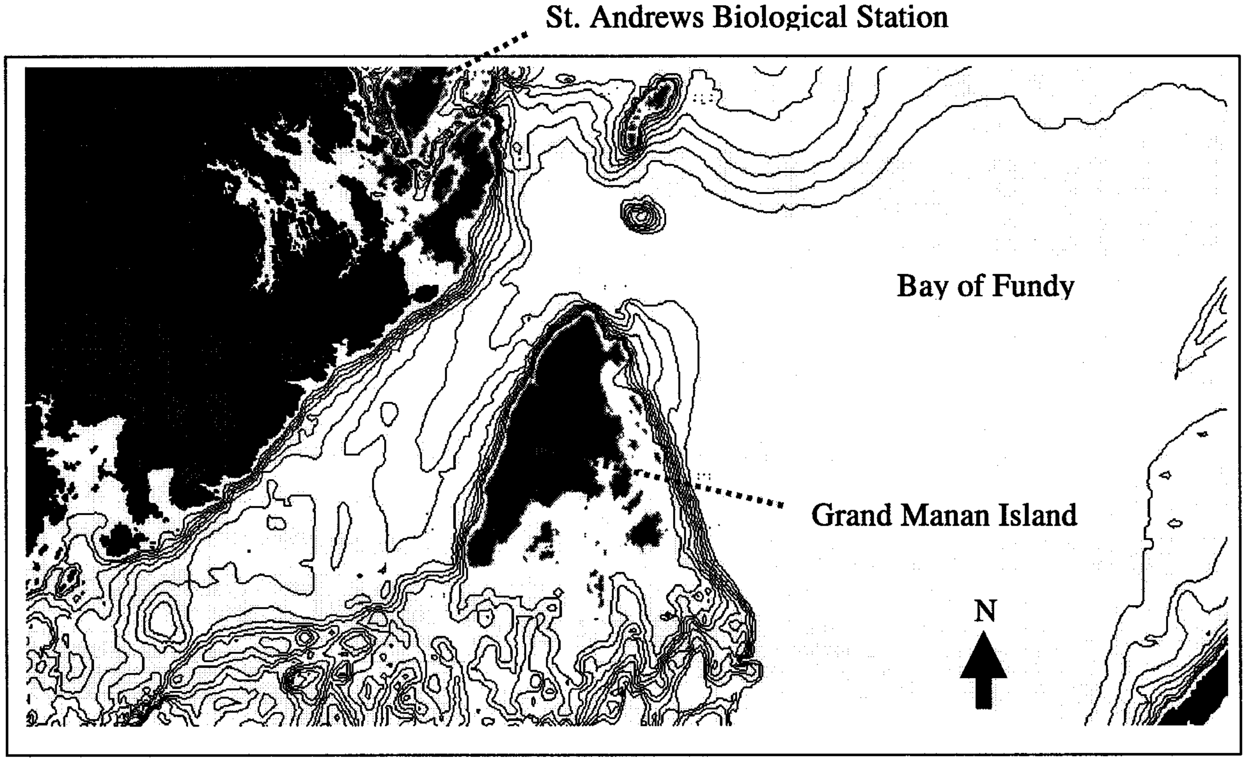


Figure 4-2 Coastal line and contour lines around Grand Manan Island situated in the Bay of Fundy

Figure 4-2 above shows the outline of the Island of Grand Manan. The contour lines demonstrate that along the Eastern shore and the Southern shore the depth of the water is increasing quickly. These shore areas are not attractive as fish farm sites nor for performing dragging or marine trapping activities. On the contrary, the Western and Northern shores of Grand Manan are with comparatively gentle slope. These areas provide excellent fish farm site possibilities.

(2) Fish Farm Sites

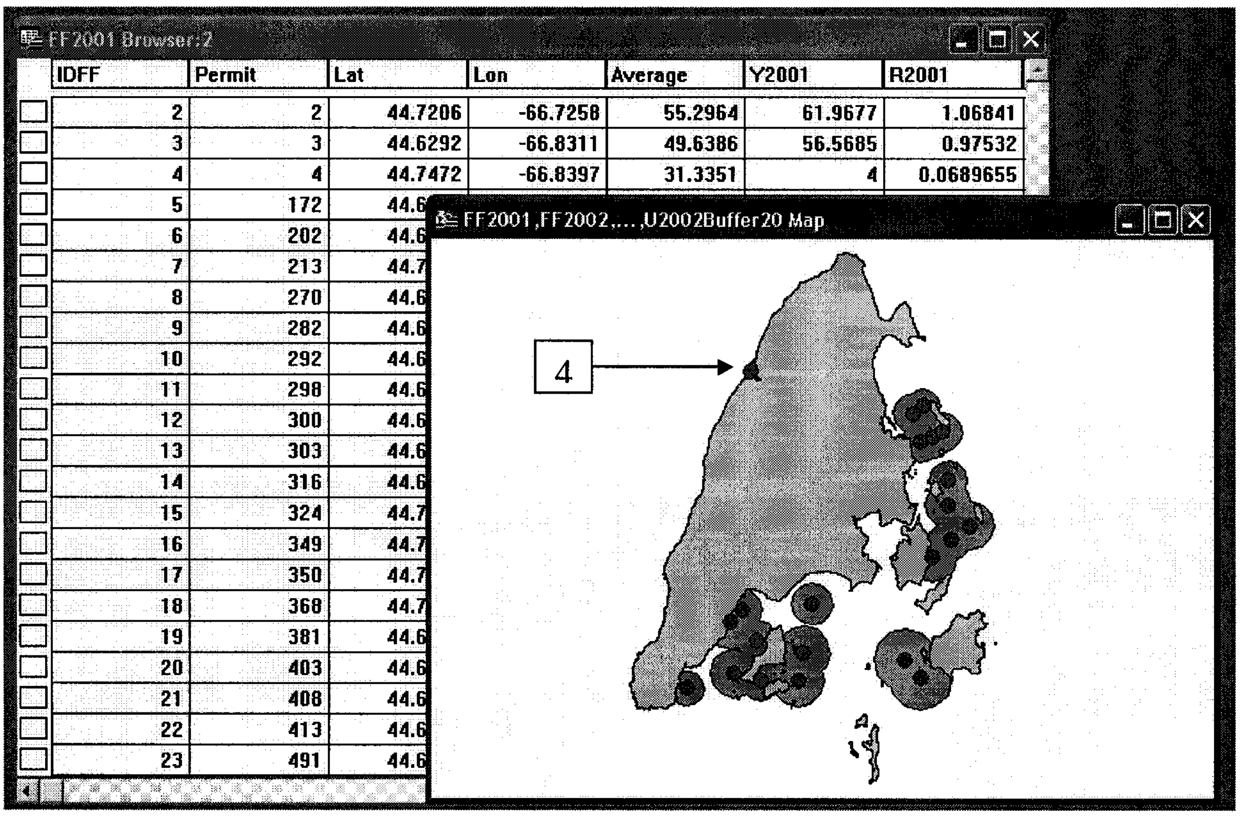


Figure 4-3 Farm site distribution and productivity buffers for the year 2001; fish farm #4 is identified by its IDFF label "4".

In the Grand Manan database, there are 5 years of fish farm site data from 1998 to 2002. During this period, the site distribution was continually changing. Some new sites were added and some old sites were closed; some sites' harvest productivities were increased and others declined. Figure 4-3 shows the site distribution of fish farms around Grand Manan in 2001. The small circles represent the location of fish farm sites and the shaded circular buffers around these are used in this analysis. The buffer size is based loosely on disguised harvest productivity data. (The actual productivity of the fish farms has been altered for reasons of data propriety.) For example, from the table in Figure 4-3, the harvest of site number 4 (IDFF = 4) was only 4 units; its buffer radius is accordingly set at 0.0689655km and, as such, is not much different from the small location circle for the fish farm. Most sites have productivity values set close to 59 units and are assigned corresponding radius of close to 1km. For site 4, it was a test or new set site in 2001 and its harvest productivity in 2002 was increased to 41.95 units.

(3) Urchin data

The original data for the urchin resource around Grand Manan included a lot of related information in Excel file format. Figure 4-4 shows part of the file of 2002 where various information is saved in corresponding columns which include LANDPO, NAME, FISHDATE, AREA, GEAR, LAT, LON, SETS, THOURS, WTLBS 10 items. These columns represent the fishing area names, locations, dates, areas, captures etc.

	A	B	C	D	E	F	G	H	I	J
1	LANDPO	NAME	FISHDATE	AREA	GEAR	LAT	LON	SETS	THOURS	WTLBS
2	25008	ALYSSA CARLEY	13/03/2002	4X S	7500	44.6	66.77	4	0	4986
3	25008	BONUS	22/01/2002	4X S	7100	44.67	66.72	0	4.2	2310
4	25008	BONUS	23/01/2002	4X S	7100	44.65	66.72	0	3.6	2400
5	25008	BONUS	24/01/2002	4X S	7100	44.65	66.72	0	4.6	2700
6	25008	BONUS	29/01/2002	4X S	7100	44.65	66.72	0	3.5	1011
7	25008	BONUS	31/01/2002	4X S	7100	44.62	66.73	0	3	635
8	25008	BONUS	08/02/2002	4X S	7100	44.62	66.72	0	4.75	750
9	25008	BONUS	18/02/2002	4X S	7100	44.63	66.73	0	3.5	1501

Figure 4-4 Urchin data provided by scientists at the St. Andrews Biological Station

In this study, only urchin area distribution, locations and yields are needed. By filtering, urchin resource location (LAT and LON) and the Total Biomass (WTLBS) data were recorded as in Figure 4-4. The evaluated unit area yield per square kilometre is estimated at 988 yield units in the year 2002. Delineated urchin distributions are concentrated along the Eastern, Southern and Northern shores of Grand Manan. The western shore area has no appreciable distribution of the urchin resource. Figure 4-5 shows the situation in 2002 where the larger buffer (radius = 2km) and purple (dark) colour represents the urchin resources and the smaller buffer (dark (red), radius = 1km) denotes the Activity area or the urchin drags area by the harvesting interests. The two small tables in the map window show the corresponding Resources layer and Activities layer which include identity number (IDResources, IDActivities), yield value (YieldR, YieldA) and the layer area (Area) etc.

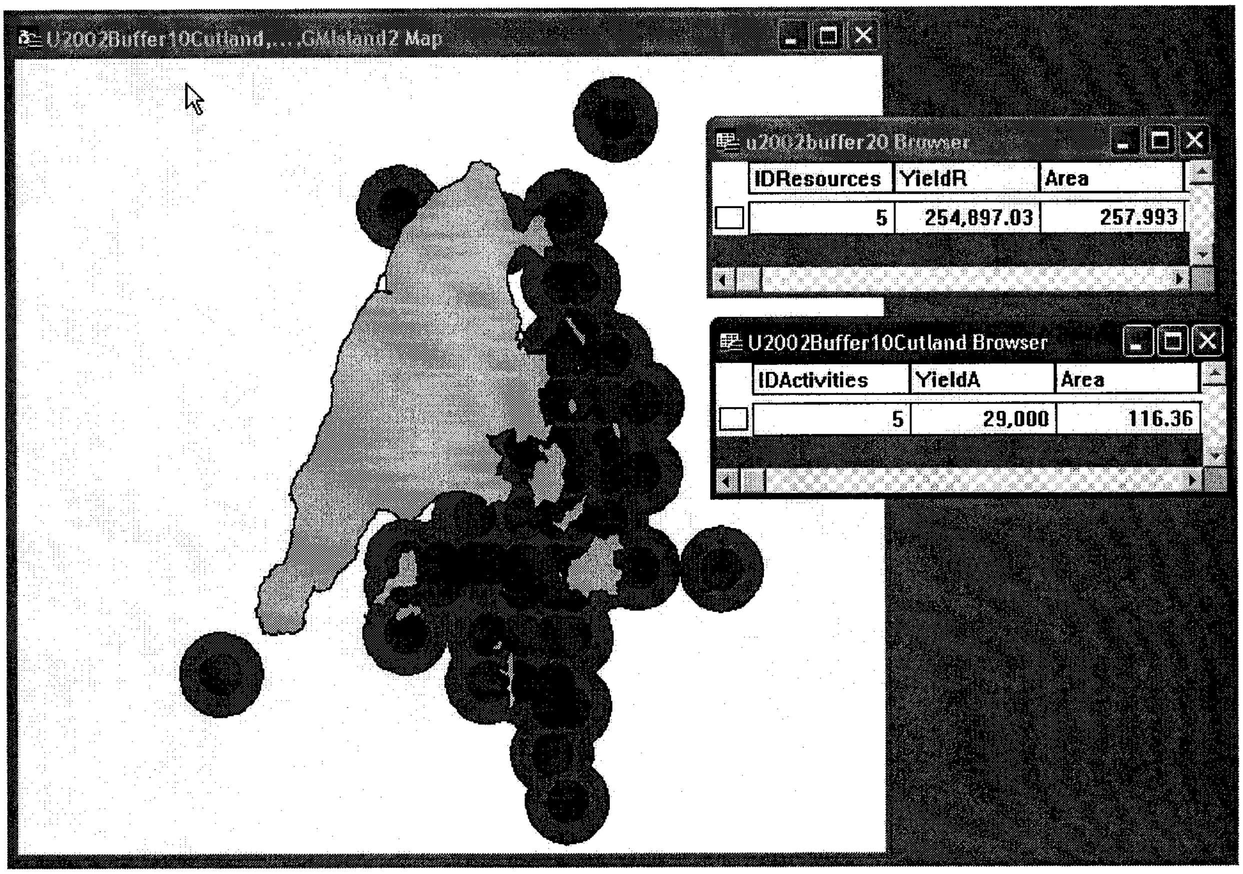
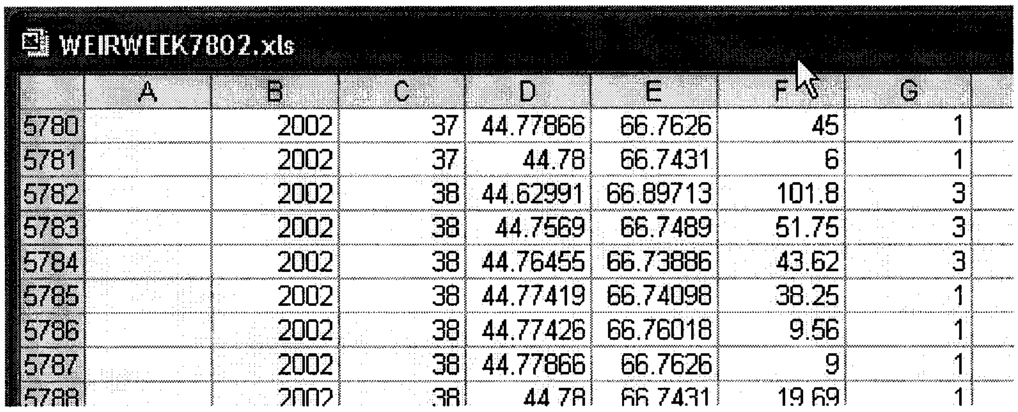


Figure 4-5 Urchin area distribution for the year 2002

(4) Herring Weir Distribution

According to the weir harvest data table (Figure 4-6), the Herring Weirs around Grand Manan Island are located and mapped, and their yields year by year evaluated. For example, the harvest in 2002 is estimated as 5379kg. Suppose the price is recorded as $2/kg for herring in this area, then the yield is recorded as $2/kg* 5379 kg = $10758. Figure 4-7 shows the distribution of year 2002 herring weir activities where the green buffer is drawn around the centre of the located weirs with a radius of 0.5km. From the figure, it is notable that most herring weirs are located along the eastern and north eastern shores of Grand Manan Island. In addition, according to the buffer, the total area of herring weir is calculated as 9.6 km^2. Therefore the unit yield of herring weir is $10758/9.6 km^2 = $1121/ km^2.



	A	B	C	D	E	F	G
5780		2002	37	44.77866	66.7626	45	1
5781		2002	37	44.78	66.7431	6	1
5782		2002	38	44.62991	66.89713	101.8	3
5783		2002	38	44.7569	66.7489	51.75	3
5784		2002	38	44.76455	66.73886	43.62	3
5785		2002	38	44.77419	66.74098	38.25	1
5786		2002	38	44.77426	66.76018	9.56	1
5787		2002	38	44.77866	66.7626	9	1
5788		2002	38	44.78	66.7431	19.69	1

Figure 4-6 Original data containing the harvests of Herring Weirs from 1978 to 2002

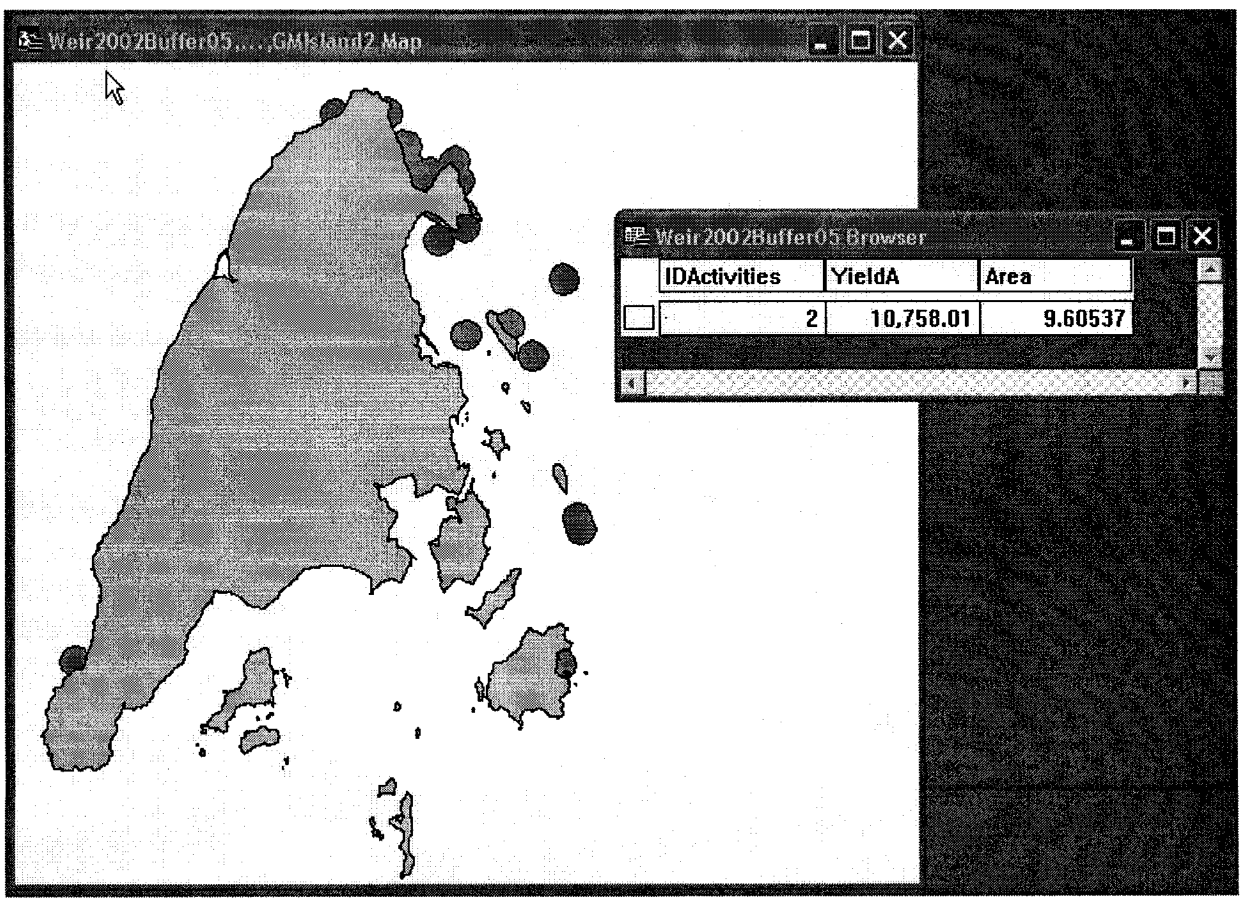


Figure 4-7 Herring weir distribution in 2002

(5) Herring Resources Distribution

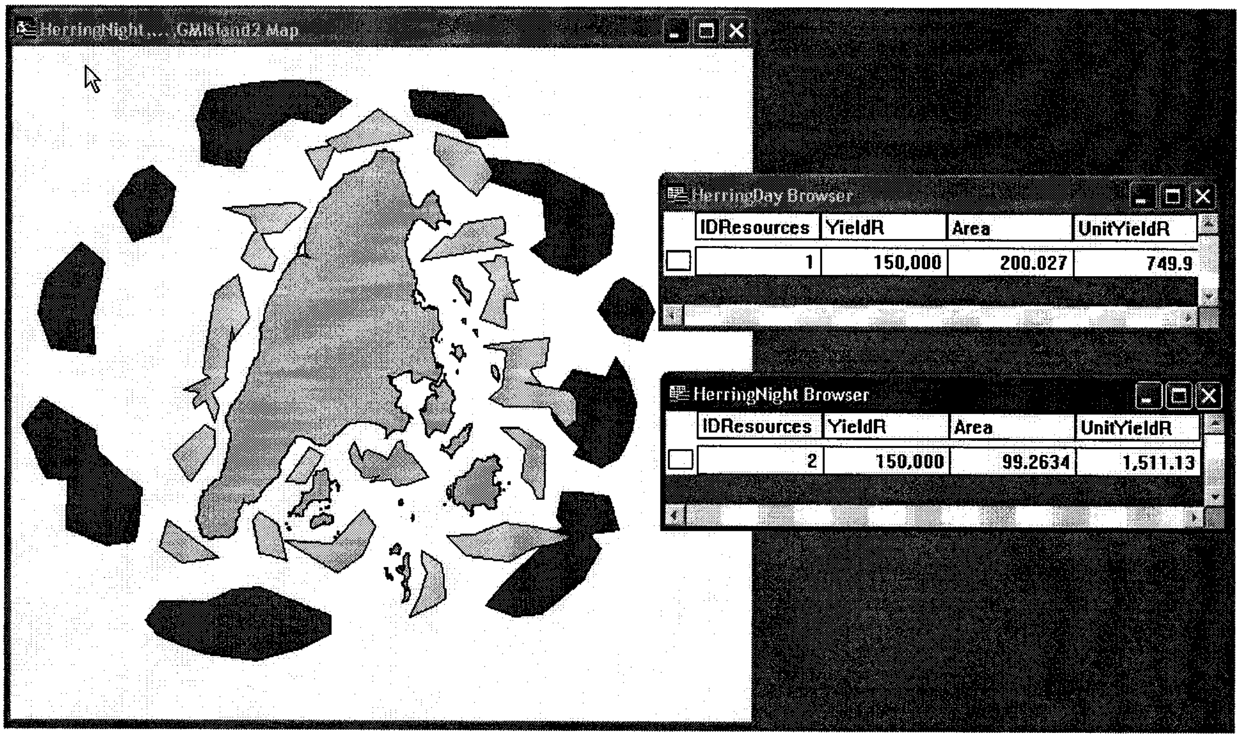


Figure 4-8 Inshore (yellow/grey) and offshore (blue/dark) distribution of herrings

Since schools of herring keep moving daily, their distribution is dynamically changing. Generally it is known that Grand Manan herring stocks migrate in the Bay of Fundy waters. In addition, in the daytime, they aggregate in the waters further offshore from Grand Manan Island and in the night return to feed closer to shore. In this research the herring resource is partitioned into "HerringDay" representing herring that stay offshore in the "staging areas", and "HerringNight" representing aggregations in space that move in the inshore feeding areas. Figure 4-8 shows the outline distributions of HerringDay (using blue/dark coloured regions) and HerringNight (using yellow/light coloured regions) on the Grand Manan map. It is necessary to point out that, while acknowledging these data for the herring resource, actual stock dynamics may vary considerably from this daily modelled behaviour both in terms of the numbers and sizes of the herring day and night aggregations as provided here. The purpose of this research is to provide a prototype method that models the actual behaviour in order to integrate the various data, and extract useful information to the decision makers. Therefore, the precision of the data is neither tested nor guaranteed and the emphasis is rather on the methodology to incorporate the modelling requirements. Thus, the inshore and offshore herring areas denoted here are based on estimated data from scientific research that is subject to revision and review.

(6) Habitat

In this research, 4 items are considered as the subcomponents of Habitat. They are: (1) Rockweed, (2) Salt Marshes, (3) Current Flow, and (4) Bottom Structure. These subcomponents were determined after discussion with scientists from the St. Andrews Biological Station familiar with the Grand Manan environment. Data on these subcomponents were kindly provided for Rockweed and Salt Marshes only. Analyses of data on current flow and bottom structure descriptions were pending and not made available for this research.

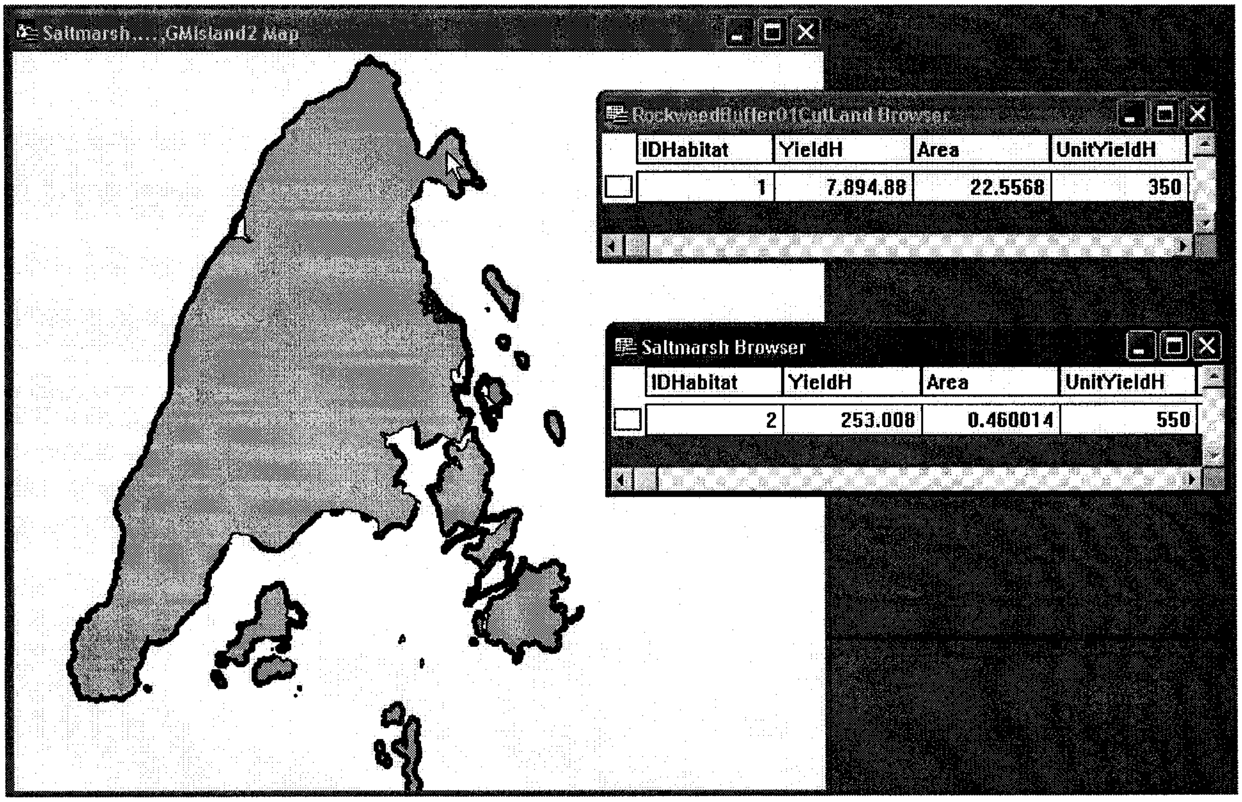


Figure 4-9 Rockweed and Salt Marsh in the Grand Manan Island

Rockweed grows along and almost covers the coastline of the Island as illustrated in the dark green shoreline areas of Figure 4-8. The tiny representation of Salt Marshes (in the dark yellow areas of Figure 4-8) is located on this map along the mid-western shore and doesn't occupy much area (only 0.46 km^2). Current Flow brings huge nutrient materials to spatial areas around the island, and the Bottom Structure helps define the living space for marine organisms.

(7) Chemical pollution

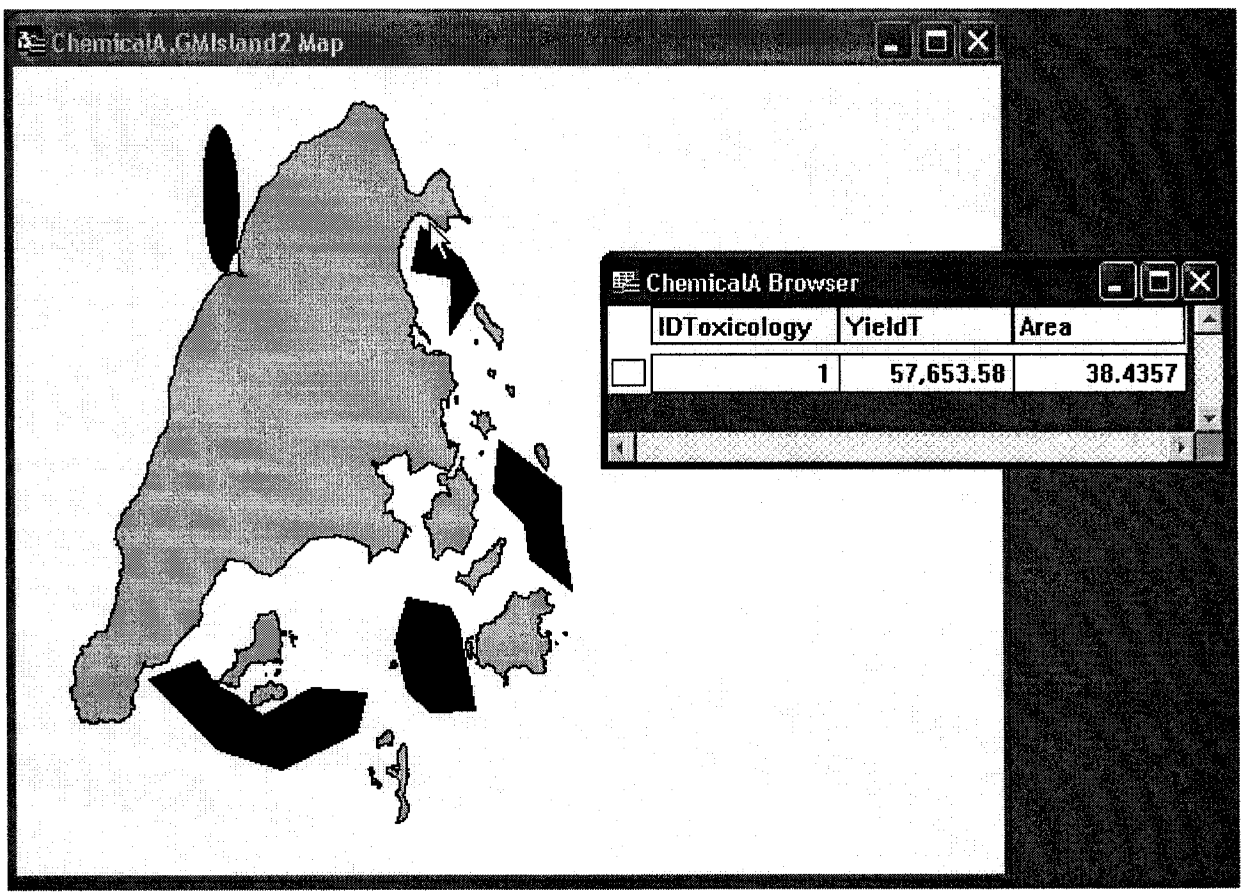


Figure 4-10 Toxicology Plume Distribution of Chemical A (created data associated with fish farms)

Ocean pollution may result from various sources. The primary definition of toxicology in this model is associated with the location and product of the Fish farm (aquaculture site) activity. Generally, it is difficult to delineate the area affected by water borne pollution or to determine the impacts this has on overlapping elements of the system. For the Grand Manan model, pollution information was forthcoming from Biological Station scientists modeled on the basis of drift analysis for a subset of the fish farms to the south of Grand Manan. In the model, this component is modeled by identifying a single unnamed chemical pollutant ("Chemical A") and its yield is defined as the cost to treat the pollution. In general, the higher the chemical yield, the greater its harm to the ambient environment. Given this intuition and the available data, Chemical A plume areas are created freely and are associated with each of the fish farms. Unit area toxicology yields are assigned a value of 1500 units. Figure 4-10 shows the corresponding map and table with Chemical A toxicology yields.

Table 4-1 Available Input Data

Component	Subcomponent	ID	Yield	Area	Unit Yield
Resources	HerringDay	1	150000	200.0	750
	HerringNight	2	150000	99.3	1511
	Lobster	3	N/A	N/A	N/A
	Scallops	4	N/A	N/A	N/A
	Urchins	5	254897	258.0	988
Habitat	Rockweed	1	7895	22.6	350
	SaltMarshes	2	253	0.5	550
	CurrentFlow	3	N/A	N/A	N/A
	BottomStructure	4	N/A	N/A	N/A
Toxicology	ChemicalA	1	57654	38.4	1501
	ChemicalB	2	N/A	N/A	N/A
	ChemicalC	3	N/A	N/A	N/A
Activities	HerringWeirs	1	10758	9.6	1121
	FishFarms	2	1427	54.2	26
	LobsterTraps	3	N/A	N/A	N/A
	ScallopDrags	4	N/A	N/A	N/A
	UrchinDrags	5	29000	116.4	249

N/A – data not available for this analysis

Generally, the available data as discussed above include 9 of the total 17 different subcomponents of the system. These data are directly obtained with appreciation from the scientists of the St. Andrews Biological Station. In some cases, some data for the Grand Manan model are estimated based on anticipated actual information. The yield-area schedule for the entire area around Grand Manan is shown in

Table 4-1 including unit yields, total yields, and area designations by subcomponent. It is necessary to stress that these input data are not categorical, i.e., the unit yield data are subject to discussion and revision to scale. This study is to develop and present a framework for solving the complex questions which are perplexing decision makers in the multicriteria coastal aquaculture management. Thus, the data provided for this illustration provide a starting point for further analysis and revision.

4.1.3 Decision making processes and participants' input

The 5 different organizations participating in the Grand Manan aquaculture governance problem were identified previously as:

(1) Local Communities

(2) Federal Scientists

(3) Industrial organizations

(4) Non Governmental Organizations

(5) Provincial Governments.

Using the pairwise comparison method introduced in Chapter 3, Methodology and Programming, various viewpoints of these 5 participants with regard to the evaluations of selected site alternatives are obtained using the AHP analysis. Appendix I shows the comparison tables.

Since an AHP or a multi-criteria structure is used, the general goal should be the same for different aquaculture options. In the process of using AHP, the core is to make pairwise comparisons for different components and determine their priorities. Therefore, for the same layer, the criteria or sub-criteria should stay the same; otherwise, the conclusions will be inconsistent or contrary to each other. This research aims to include all necessary items or components of the study area within the same hierarchical structure and this is the reason of using identified criteria and sub-criteria to evaluate different aquaculture options.

Various viewpoints are reflected by the weights that are assigned to different alternatives and factors by the different participants. Table 4-2 below provides the results of the pairwise comparisons attributed to the 5 participant groups for the same multicriteria problem involving the same components and subcomponents for the review of each participant group. In other words, the difference of the attributed weights represents the difference of their viewpoints. Analyzing and comparing these weights may help decision makers to find appropriate ways to solve the conflicts between different organizations.

(1) The Attributed weights on the 4 components (R, H, T and A)

From the graph in Figure 4-11 below (a graphical representation of the weights provided in Table 4-2), it is easy to see that different organizations have quite different interpretations of the components of the problem. As anticipated, Local Communities attach importance to the Toxicology and Habitat components, and apply less weight to Activities and Resources. Scientists however put Resources at the highest weighted position and Activities (exploitation) at the lowest consistent with the scientific mandate for conservation of all natural resources. Industrial Organizations pay much more attention to the importance of Activities. This is understandable since only activities can bring direct economic profits and that is the basis they exist at all. Industrial Organizations attach lower weighting to Habitat and Toxicology components. NGOs do not belong to the Government. From their viewpoint, Toxicology is regarded as the most important negative component in the system. Activities are seen as having a secondary negative impact on the natural system. As for the Provincial Government, its evaluations for the 4 components are somewhat close to that of the Industrial Organizations – Activities are ranked as the first and Resources as the second most important components. Differences arise with respect to the ranking of the Toxicology and the Habitat components. The

Provincial Government puts Toxicology before the Habitat but the Industrial Organizations do the opposite.

Table 4-2 Attributed weights of the 5 participants on the 4 components: R, H, T and A

	Local Communities (LC)	Federal Scientists (FS)	Industrial Organizations (IO)	Non-Governmental Organizations (NGO)	Provincial Governments (PG)
Resources (R)	0.147	0.546	0.256	0.235	0.226
Habitat (H)	0.302	0.217	0.124	0.235	0.075
Toxicology (T)	0.435	0.163	0.082	0.439	0.185
Activities (A)	0.116	0.075	0.538	0.083	0.514

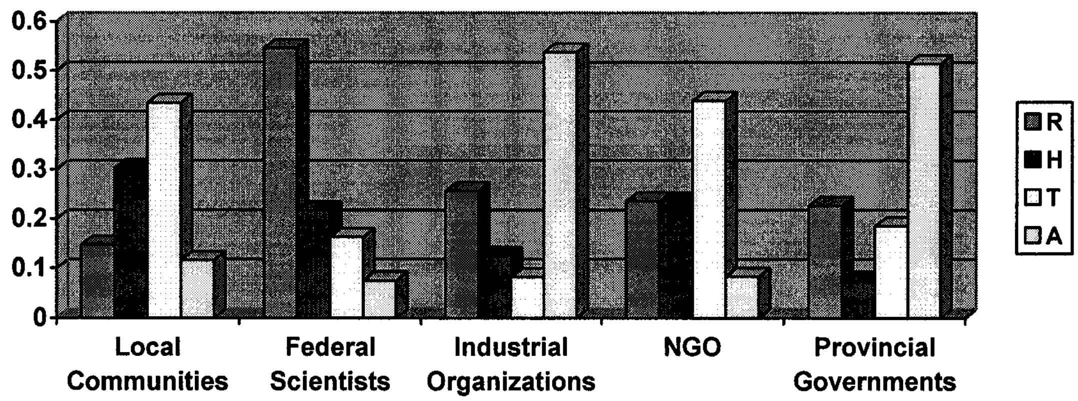


Figure 4-11 Graphic view of the Attributed weights of the 5 participants on the 4 components: R, H, T and A

(2) Different evaluations for each item of different components

Different components contain different membership, and therefore different organizations are seen to have quantitatively different importance evaluations for each member. As previously noted, various evaluations of the 5 participants are summarized into different tables and graphs. In the following sections the rankings of the participants among the various subcomponents of the model are presented.

(a) Resources (R)

Table 4-3 Attributed weights of the 5 participants on the 5 Resources subcomponents: HD, HN, L, S, U

	Local Communities (LC)	Federal Scientists (FS)	Industrial Organizations (IO)	Non-Governmental Organizations (NGO)	Provincial Governments (PG)
HerringDay (HD)	0.200	0.200	0.079	0.200	0.096
HerringNight (HN)	0.200	0.200	0.079	0.200	0.096
Lobster (L)	0.200	0.200	0.276	0.200	0.330
Scallops (S)	0.200	0.200	0.523	0.200	0.330
Urchins (U)	0.200	0.200	0.043	0.200	0.148

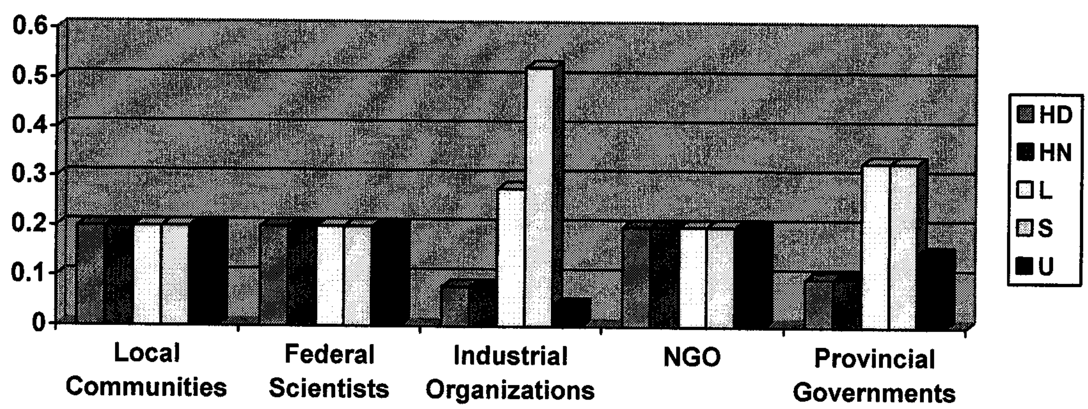


Figure 4-12 Attributed weights of the 5 participants on the 5 items (HD, HN, L, S, U) of Resources

The membership of Resources includes HerringDay, HerringNight, Lobster, Scallops and

Urchins for a total of 5 subcomponents. The weighting results attributed to the participants for these subcomponents are presented below in Table 4-3 and Figure 4-12.

The graph of Figure 4-12 shows that Local Communities, Scientists and NGO believe the importance of HerringDay, HerringNight, Lobster, Scallops and Urchins are the same, without any difference. However, Industrial Organizations evaluate Scallops as a more important commercial species than the others. Industrial Organizations value the importance of scallops to be 0.523/0.043 or about 13 times as important as Urchins. In addition, Lobster also is attributed a higher rank (based on actual dollar value) to this group. The reason for this kind of ranking attributed to Scallops and Lobster by this group is due to the high profits these activities yield compared with the lower relative value of Urchins. As for the Provincial Government participants, Scallops and Lobsters are assigned equal high weights. These weights are higher than the weight attributed to Herring and Urchins by this group, again reflective of the relative economic value to the province of these resources.

(b) Habitat (H)

Table 4-4 Attributed weights of the 5 participants on the 5 Habitat subcomponents: RW, SM, CF, BS

	Local Communities (LC)	**Federal Scientists (FS)**	**Industrial Organizations (IO)**	**Non-Governmental Organizations (NGO)**	**Provincial Governments (PG)**
Rockweed (RW)	0.292	0.250	0.375	0.375	0.301
SaltMarshes (SM)	0.479	0.250	0.125	0.375	0.410
CurrentFlow (CF)	0.132	0.250	0.125	0.125	0.171
BottomStructure (BS)	0.098	0.250	0.375	0.125	0.118

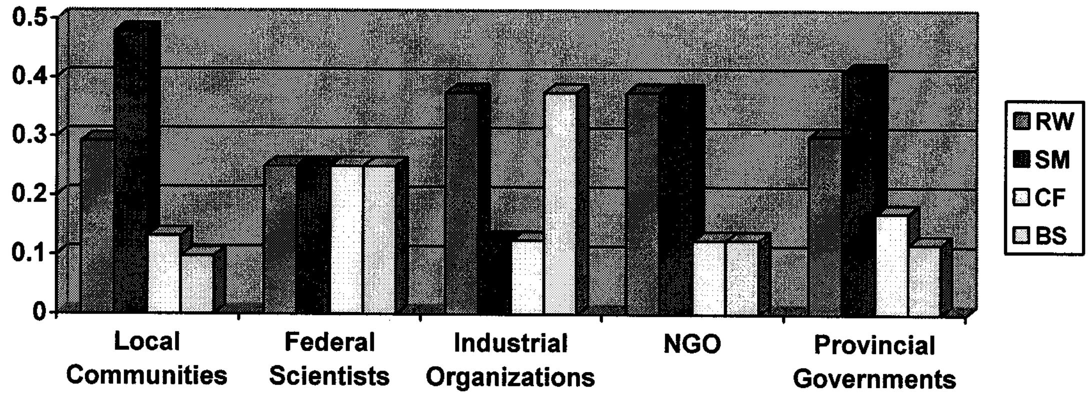


Figure 4-13 Attributed weights of the 5 participants on the 5 Habitat subcomponents: RW, SM, CF, BS

The membership of Habitat is Rockweed, Salt Marshes, Current Flow and Bottom Structure.

All groups are attributed with the understanding that Rockweed is an important Habitat subcomponent, although Local Communities are assigned Salt Marsh as the most important Habitat subcomponent. Local Communities are quite different from the Industrial Organizations who are place more weight on Rockweed. A possible reason for this attribution is that Industrial Organizations consider Rockweed and Bottom Structure to be more important for commercial fish activities.

Similarly, Scientists do not distinguish between the 4 different types of Habitats. All of them are assigned equal weights with the same scientific valuation.

NGOs equate the pairs Rockweed and Salt Marshes, and Current Flow and Bottom Structure. The former pair is valued somewhat higher than the later pair.

As for the Provincial Government, Salt Marshes are ranked highest. Next, Rockweed, Current Flow and Bottom Structure in turn followed one-by-one. This ranking order is similar to that of the Local Communities.

(c) Toxicology (T)

Only 3 different chemical pollutants are provided for as the subcomponent membership in this group. The labels are arbitrarily assigned as chemicals A, B, C and, apart from being associated with fish farms as sources, these labels do not currently identify any particular toxin.

Table 4-5 Attributed weights of the 5 participants on the 3 Toxicology subcomponents: CA, CB, and CC

	Local Communities (LC)	Federal Scientists (FS)	Industrial Organizations (IO)	Non-Governmental Organizations (NGO)	Provincial Governments (PG)
ChemicalA (CA)	0.691	0.691	0.691	0.691	0.691
ChemicalB (CB)	0.218	0.218	0.218	0.218	0.218
ChemicalC (CC)	0.091	0.091	0.091	0.091	0.091

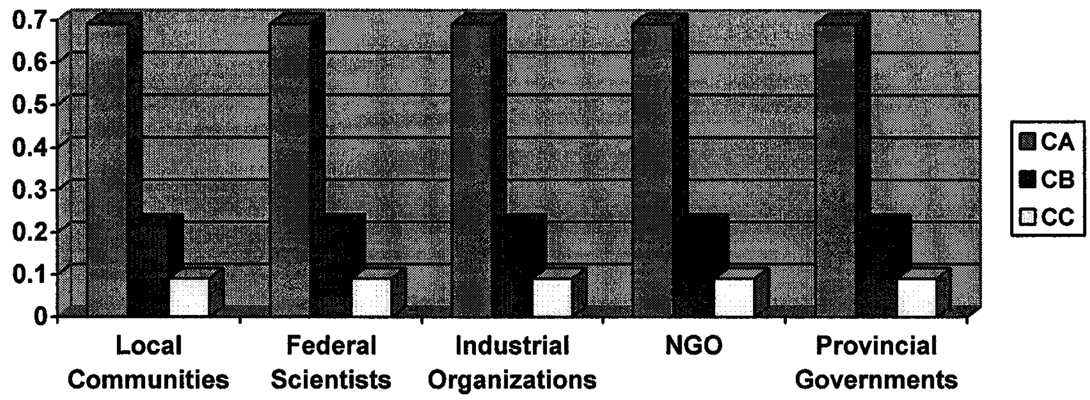


Figure 4-14 Attributed weights of the 5 participants on the 3 Toxicology subcomponents: CA, CB, CC

Real attributed Toxicology data for Grand Manan are not currently available. However, the procedures for understanding the hazards of different chemical materials are well-determined. Accordingly, should the data be made available, the process described here can accommodate this information.

(d) Activities (A)

The total subcomponents of Activities include Herring Weirs, Fish Farms, Lobster Traps, Scallop Drags and Urchin Drags. The weighting results attributed to the participants for these subcomponents are presented below in Table 4-6 and Figure 4-15.

Table 4-6 Attributed weights of the 5 participants on the 5 Activities subcomponents: HW, FF, LT, SD, UD

	Local Communities (LC)	**Federal Scientists (FS)**	**Industrial Organizations (IO)**	**Non-Governmental Organizations (NGO)**	**Provincial Government (PG)**
HerringWeirs (HW)	0.141	0.380	0.087	0.200	0.057
FishFarms (FF)	0.141	0.156	0.147	0.200	0.358
LobsterTraps (LT)	0.307	0.326	0.264	0.200	0.158
ScallopDrags (SD)	0.281	0.095	0.462	0.200	0.158
UrchinDrags (UD)	0.130	0.044	0.039	0.200	0.269

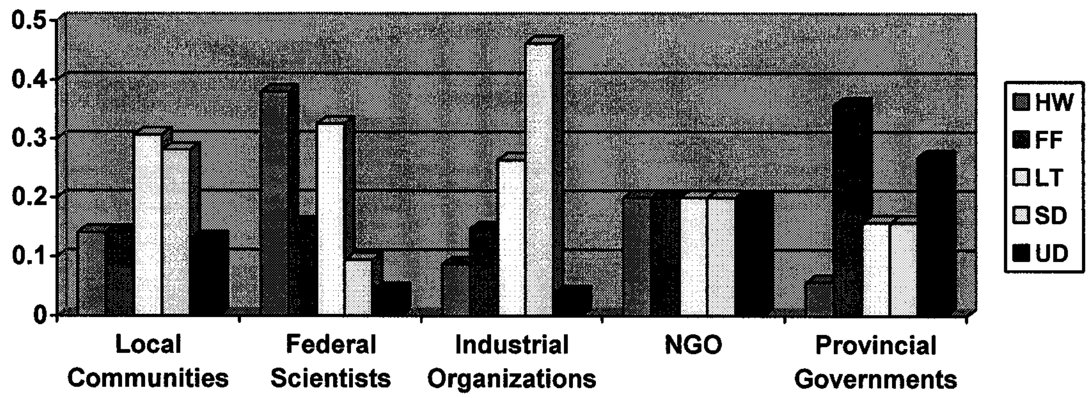


Figure 4-15 Attributed weights of the 5 participants on the 5 Activities subcomponents: HW, FF, LT, SD, UD

Figure 4-15 shows that the NGO group does not differentiate among the 5 Activities subcomponents. The Local Communities attribute more importance to Lobster Traps and Scallop Drags than to Herring Weirs, Fish Farms and Urchin Drags. Scientists prefer the noninvasive, passive exploitation of Herring Weirs and because weirs are judged to be less destructive on the environment. On the contrary, since draggers for scallops and urchins may cause serious affects on the environment, their weights are ranked relatively very low by Scientists. Comparatively, Lobster Traps having higher weights than Fish Farms reflects similar considerations. For Industrial Organizations, profits are expected to drive the importance role in their priority setting. Their evaluations imply that Scallop Drags brings the highest profit, next are Lobster Traps, Fish Farm, Herring Weirs and Urchin Drags. As for the Provincial Government, Fish Farms are given high consideration related to the greater provincial jurisdiction. Urchin as a new cultivated species has a good future as reflected in its relative high weight. Traditional Lobster Traps and Scallop Drags' scores are close the average.

4.2 Experiments

A number of experiments were applied to the Grand Manan application using the MapInfo evaluations and the ranking attributions of the participants presented for the system problem. The basic experimental process steps follow the flow chart, Figure 3-11. The experimental process is also summarized here in the following several steps:

(1) Open the main model GIS frame and select which year's data to use.
(The default setting is 2002.)

(2) Load the necessary map layers for the problem at hand.
The buttons: Resources, Habitat, Toxicology and Activities upload the spatial data.

(3) Extract information from your enclosed areas.
First, designate the filename which will be used to store the data to be extracted; then select an area by clicking the button named Select Region and using the selection tools including polygon, rectangle, ellipse and rounded rectangle settings. Finally, push the "Do Execution" button to extract the information.

(4) Output extracted information to *Expert Choice 2000* to do Pairwise analysis.
Use the extracted information and the selected participant group to open the established AHP models in the *Expert Choice 2000* software. Examine the results in *Expert Choice* for the participants' ranking of the selected areas.

The results of the participants' rankings provide the information for further negotiation and decision support. It is not the purpose of this research to use the proposed decision support system to resolve the differences among the participants with regard to site selection and ranking. Rather, this quantified information is expected to be made available to all participants for their full information and understanding. This knowledge leads to the negotiation that is required to make a single decision in cases like this.

In the following section several experiments are undertaken to provide participants' rankings. The results are analysed to provide insight into how negotiations could logically proceed under different conditions.

Firstly, the total study area is analysed by taking it as the study object. Next two areas are sampled and compared. In order to make it general, the comparison is specially designed including equal and unequal size area comparisons. Furthermore, a group of 4 areas of equal size area and similar geographical location are evaluated for the cases that included and excluded a fish farm for comparative purposes.

4.2.1 Total study area

In order to validate and demonstrate understanding of the general information, and to help effectively evaluate the coastal zone sites for aquaculture, the whole study region is selected to be the analyzed and inventoried. Figure 4-16 shows the map of the selected area with all available layers included as per the legend.

As can be seen from the map, it is clear that the eastern coast off Grand Manan is an extremely fertile and active marine area. Most resources of this study are concentrated along this coastline. As well, it is also very suited to sitings for fish farms or to develop other fishery-related activities. The multiple overlapping layers provide a challenge for the current study.

Using the model, the whole study region was selected and all overlapping (and not overlapping) information were extracted to a table, Table 4-7. This table contains the entire overlapping definitions for Grand Manan. There are 110 total different designations for the whole study area as recorded in each of the rows of Table 4-7 of total area of 1295.8 km^2.

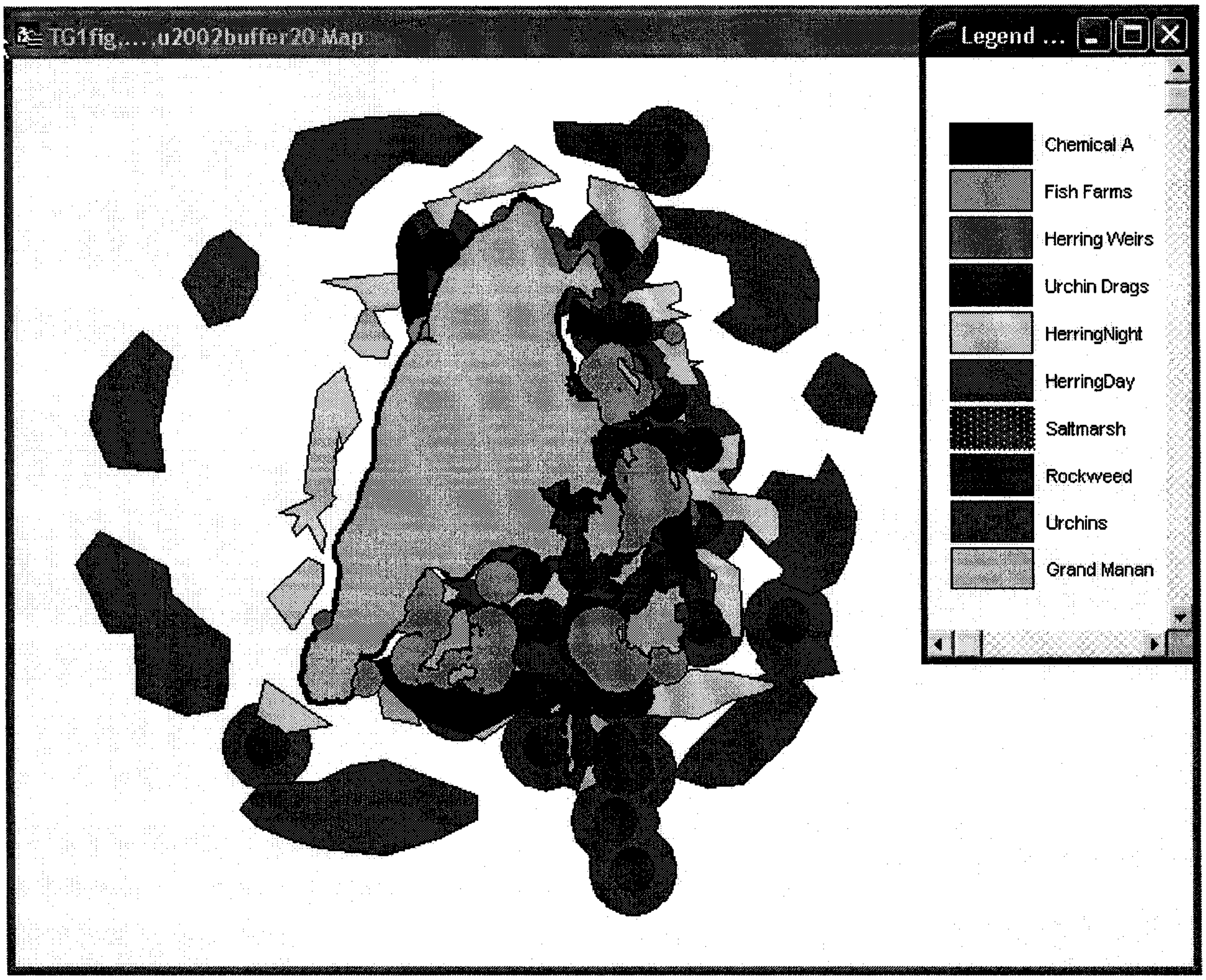


Figure 4-16 MapInfo Overlay information for the whole study region of Grand Manan

Table 4-7 Extracted information from the whole study region

ID Resources	ID Habitat	ID Toxicology	ID Activities	Yield Resources	Yield Habitat	Yield Toxicology	Yield Activities	Area
0	0	0	0	0.0	0.0	0.0	0.0	1295.8
0	0	0	5	0.0	0.0	0.0	29000.0	116.4
0	0	0	2	0.0	0.0	0.0	1427.3	54.2
0	0	0	52	0.0	0.0	0.0	8260.4	30.0
0	0	0	1	0.0	0.0	0.0	10758.0	9.6
0	0	0	51	0.0	0.0	0.0	4800.4	3.5
0	0	0	21	0.0	0.0	0.0	1948.1	1.7
0	0	0	521	0.0	0.0	0.0	1588.2	1.1
0	0	1	0	0.0	0.0	57537.2	0.0	38.4

0	0	1	5	0.0	0.0	24413.0	4056.2	16.3
0	0	1	2	0.0	0.0	22793.8	400.4	15.2
0	0	1	52	0.0	0.0	13737.6	2523.8	9.2
0	0	1	1	0.0	0.0	1907.9	1424.5	1.3
0	0	1	51	0.0	0.0	833.9	761.2	0.6
0	0	1	21	0.0	0.0	649.4	496.3	0.4
0	0	1	521	0.0	0.0	325.4	302.8	0.2
0	2	0	0	0.0	252.8	0.0	0.0	0.5
0	2	0	5	0.0	5.2	0.0	2.4	0.0
0	2	0	2	0.0	10.9	0.0	0.5	0.0
0	2	0	52	0.0	5.2	0.0	2.6	0.0
0	1	0	0	0.0	7894.9	0.0	0.0	22.6
0	1	0	5	0.0	3712.0	0.0	2643.2	10.6
0	1	0	2	0.0	2457.5	0.0	185.0	7.0
0	1	0	52	0.0	1482.5	0.0	1167.2	4.2
0	1	0	1	0.0	644.8	0.0	2063.3	1.8
0	1	0	51	0.0	177.8	0.0	695.5	0.5
0	1	0	21	0.0	61.2	0.0	200.6	0.2
0	1	0	521	0.0	61.2	0.0	244.2	0.2
0	21	0	0	0.0	13.6	0.0	0.0	0.0
0	1	1	0	0.0	190.4	815.8	0.0	0.5
0	1	1	5	0.0	41.5	177.8	29.5	0.1
0	1	1	2	0.0	165.6	709.8	12.5	0.5
0	1	1	52	0.0	40.8	175.1	32.2	0.1
0	21	0	5	0.0	3.5	0.0	1.0	0.0
0	21	0	2	0.0	3.5	0.0	0.1	0.0
0	21	0	52	0.0	3.5	0.0	1.1	0.0
5	0	0	0	250604.2	0.0	0.0	0.0	253.6
5	0	0	5	114804.3	0.0	0.0	28959.8	116.2
5	0	0	2	45316.2	0.0	0.0	1208.4	45.9
5	0	0	52	29615.6	0.0	0.0	8260.4	30.0
5	0	0	1	7681.8	0.0	0.0	8708.2	7.8
5	0	0	51	3463.8	0.0	0.0	4800.4	3.5
5	1	1	5	117.1	41.5	177.8	29.5	0.1
5	0	0	21	1679.0	0.0	0.0	1948.1	1.7
5	0	0	521	1124.3	0.0	0.0	1588.2	1.1
5	2	0	0	304.6	169.6	0.0	0.0	0.3
5	1	1	52	115.3	40.8	175.1	32.2	0.1
5	0	1	0	31785.9	0.0	48257.9	0.0	32.2
5	0	1	5	16080.0	0.0	24413.0	4056.2	16.3
5	0	1	2	12757.6	0.0	19368.9	340.2	12.9
5	0	1	52	9048.5	0.0	13737.6	2523.8	9.2
5	0	1	1	1241.8	0.0	1885.4	1407.8	1.3
5	0	1	51	549.3	0.0	833.9	761.2	0.6
5	2	0	5	9.3	5.2	0.0	2.4	0.0
5	0	1	21	427.8	0.0	649.4	496.3	0.4

5	2	0	2	19.6	10.9	0.0	0.5	0.0
5	0	1	521	214.4	0.0	325.4	302.8	0.2
5	2	0	52	9.3	5.2	0.0	2.6	0.0
5	1	0	0	16383.7	5803.9	0.0	0.0	16.6
5	1	0	5	10478.4	3712.0	0.0	2643.2	10.6
5	1	0	2	5848.6	2071.9	0.0	156.0	5.9
5	1	0	52	4184.8	1482.5	0.0	1167.2	4.2
5	1	0	1	1396.4	494.7	0.0	1583.0	1.4
5	1	0	51	501.8	177.8	0.0	695.5	0.5
5	1	0	21	172.9	61.2	0.0	200.6	0.2
5	21	0	0	11.3	10.3	0.0	0.0	0.0
5	1	1	0	254.0	90.0	385.6	0.0	0.3
5	1	0	521	172.9	61.2	0.0	244.2	0.2
5	1	1	2	185.5	65.7	281.6	4.9	0.2
5	21	0	5	3.8	3.5	0.0	1.0	0.0
5	21	0	2	3.8	3.5	0.0	0.1	0.0
5	21	0	52	3.8	3.5	0.0	1.1	0.0
2	0	0	0	150000.0	0.0	0.0	0.0	99.3
2	0	0	5	27450.4	0.0	0.0	4527.3	18.2
2	0	0	2	6982.7	0.0	0.0	121.7	4.6
2	0	0	52	1781.0	0.0	0.0	324.8	1.2
2	0	0	1	2070.4	0.0	0.0	1534.5	1.4
2	0	0	51	1364.1	0.0	0.0	1236.0	0.9
2	0	0	21	408.0	0.0	0.0	309.5	0.3
2	0	0	521	356.3	0.0	0.0	329.1	0.2
2	0	1	0	17101.9	0.0	16975.9	0.0	11.3
2	0	1	5	4755.2	0.0	4720.1	784.3	3.1
2	0	1	2	2254.6	0.0	2238.0	39.3	1.5
2	0	1	52	954.3	0.0	947.3	174.0	0.6
2	0	1	1	732.5	0.0	727.1	542.9	0.5
2	0	1	51	697.6	0.0	692.4	632.1	0.5
2	0	1	21	356.2	0.0	353.6	270.2	0.2
2	0	1	521	327.8	0.0	325.4	302.7	0.2
52	0	0	521	589.3	0.0	0.0	329.1	0.2
52	0	1	51	1153.7	0.0	692.4	632.1	0.5
52	0	1	21	589.1	0.0	353.6	270.2	0.2
52	0	0	0	118363.4	0.0	0.0	0.0	47.4
52	0	0	5	45397.9	0.0	0.0	4527.3	18.2
52	0	0	2	10346.8	0.0	0.0	109.1	4.1
52	0	0	52	2945.4	0.0	0.0	324.8	1.2
52	0	0	1	2799.4	0.0	0.0	1254.6	1.1
52	0	0	51	2256.0	0.0	0.0	1236.0	0.9
52	0	0	21	674.7	0.0	0.0	309.5	0.3
52	0	1	521	542.1	0.0	325.4	302.7	0.2
52	0	1	0	22794.5	0.0	13681.4	0.0	9.1
52	0	1	5	7864.2	0.0	4720.1	784.3	3.1

52	0	1	2	3243.8	0.0	1947.0	34.2	1.3
52	0	1	52	1578.2	0.0	947.3	174.0	0.6
52	0	1	1	1211.4	0.0	727.1	542.9	0.5
1	0	0	0	149999.2	0.0	0.0	0.0	200.0
1	0	0	5	1838.7	0.0	0.0	611.1	2.5
51	0	0	0	18615.6	0.0	0.0	0.0	10.7
51	0	0	5	4261.2	0.0	0.0	611.1	2.5
21	0	0	0	11648.5	0.0	0.0	0.0	5.2
521	0	0	0	3356.1	0.0	0.0	0.0	1.0

This is basic output for the input data where each line represents one composition of different possible layers. The total of 110 lines represents 110 different composition types in the study area to be evaluated.

According to the ID columns which contain the components IDResources, IDHabitat, IDToxicology and IDActivities, it is not difficult to find that the maximum overlapped layer number is 6, that only occurs at an area and the corresponding ID values are IDResources=52, IDHabitat=0, IDToxicology=1 and IDActivities=521. This overlap is interpreted as the intersection of areas including (1) Herring Day (IDResource=2), Urchins (IDResource=5), Chemical A (IDToxicology=1), Herring Weirs (IDActivities=1), Fish Farms (IDActivities=2) and Urchin Drags (IDActivities=5). The overlapped area is only 0.2 square kilometre.

Some layers have no overlap, that is, it is impossible to find these layers' ID number appearing on the same line as another. For example, Herring Day layer (IDResources=1) and Salt Mashes layer (IDHabitat=2) never exist in the same line. This is because the Herring Day layer represents the staging area of herring in the day time, and it is far away from the Grand Manan shoreline whereas the Salt Marshes layer is located in a relatively very small inshore area.

On the contrary, some layers are always overlapped with others. For example, the Urchins layer (IDResources=5) is always superposed with the Urchin Drags layer (IDActivities=5). This is due to the fact that the activity of urchin drags occurs in the same area inhabiting by the sedentary urchin resource.

As pointed out previously, the overlapped layer will affect the original yields in the same area. The effect may be positive or negative depending on the definition of the overlapping rules and what layers are overlapped. In the process of running *Expert Choice 2000*, it is necessary to standardize each analysed variable. That requires dealing with each extracted component by associating it with corresponding maximum and minimum yield values.

Theoretically, it is possible to find the maximum and minimum by analyzing the output table for the whole study area. For example, for Herring Day, from the overlapping rules, the maximum yield value must be produced at a specific area where this resource yield is augmented by other complementary Resources and Habitat layers and without any Chemical and Activities layers. Similarly, the minimum Herring Day yield must be produced at a specific area that has significant overlap with Chemical and Activities layers.

As an example, let us examine how to obtain the limited range theoretically from the overlapping rules. For convenience, the following abbreviations are used to simplify the 17 variables as Table 4-8.

Table 4-8 Abbreviations of 17 subcomponent variables

HD	Herring Day	**HN**	Herring Night	**LB**	Lobster
SC	Scallops	**UR**	Urchins	**RW**	Rockweed
SM	Salt Marshes	**CF**	Current Flow	**BS**	Bottom Structure
CA	Chemical A	**CB**	Chemical B	**CC**	Chemical C
HW	Herring Weirs	**FF**	Fish Farms	**LT**	Lobster Traps
SD	Scallop Drags	**UD**	Urchin Drags		

The abbreviations also represent the layer yields in the overlapped areas. By checking the possible overlapping layers from the output table of the whole Grand Manan, and using the overlapping rules, the formulae which are used to calculate the maximum yields of per unit area (km^2) in the study region are derived as follows:

- Herring Day Maximum overlap yield

$$HD = HD + (HD+HN)/2 + (HD+UR)/2 \quad (4\text{-}1)$$

- Herring Night Maximum overlap yield

$$HN = HN + (HN+ND)/2 + (HN+UR)/2 \quad (4\text{-}2)$$

- Urchins Maximum overlap yield

$$UR = UR + (UR+HD)/2 + (UR+HN)/2 + (UR+RW)/2 + (UR+SM)/2 \quad (4\text{-}3)$$

- Rockweed Maximum overlap yield

$$RW = RW + (RW+SM)/2 + (RW+UR)/2 \quad (4\text{-}4)$$

- Salt Marshes Maximum overlap yield

$$SM = SM + (SM+RW)/2 + (SM+UR)/2 \quad (4\text{-}5)$$

- Chemical A Maximum overlap yield

$$CA = CA + HN + UR + RW + HW + FF + UD \quad (4\text{-}6)$$

- Herring Weirs Maximum overlap yield

$$HW = HW + (HW+HN)/2 + (HW+UR)/2 + (HW+RW)/2 \quad (4\text{-}7)$$

- Fish Farms Maximum overlap yield

$$FF = FF + (FF+HN)/2 + (FF+UR)/2 + (FF+RW)/2 + (FF+SM)/2 \quad (4\text{-}8)$$

- Urchin Drags Maximum overlap yield

$$UD = UD + (UD+HD)/2 + (UD+HN)/2 + (UD+RW)/2 + (UD+SM)/2 \quad (4\text{-}9)$$

Similarly, the minimum formulae are derived for each of the nine subcomponents for which data are available. From these analyses, it is found that the evaluated range (maximum-minimum) can be very large. This is because the evaluated theoretical maximum or minimum may not exist in fact. Consequently, in order to increase the effectiveness of analyzing these results, a new method based on empirical data for Grand Manan is examined. This method selectively chooses a series of specific areas, computing each component value in these areas, and then taking the extreme values from these results as the maximum and minimum.

Figure 4-17 shows the selected specific areas in the study region and Table 4-9 shows the corresponding extracted results.

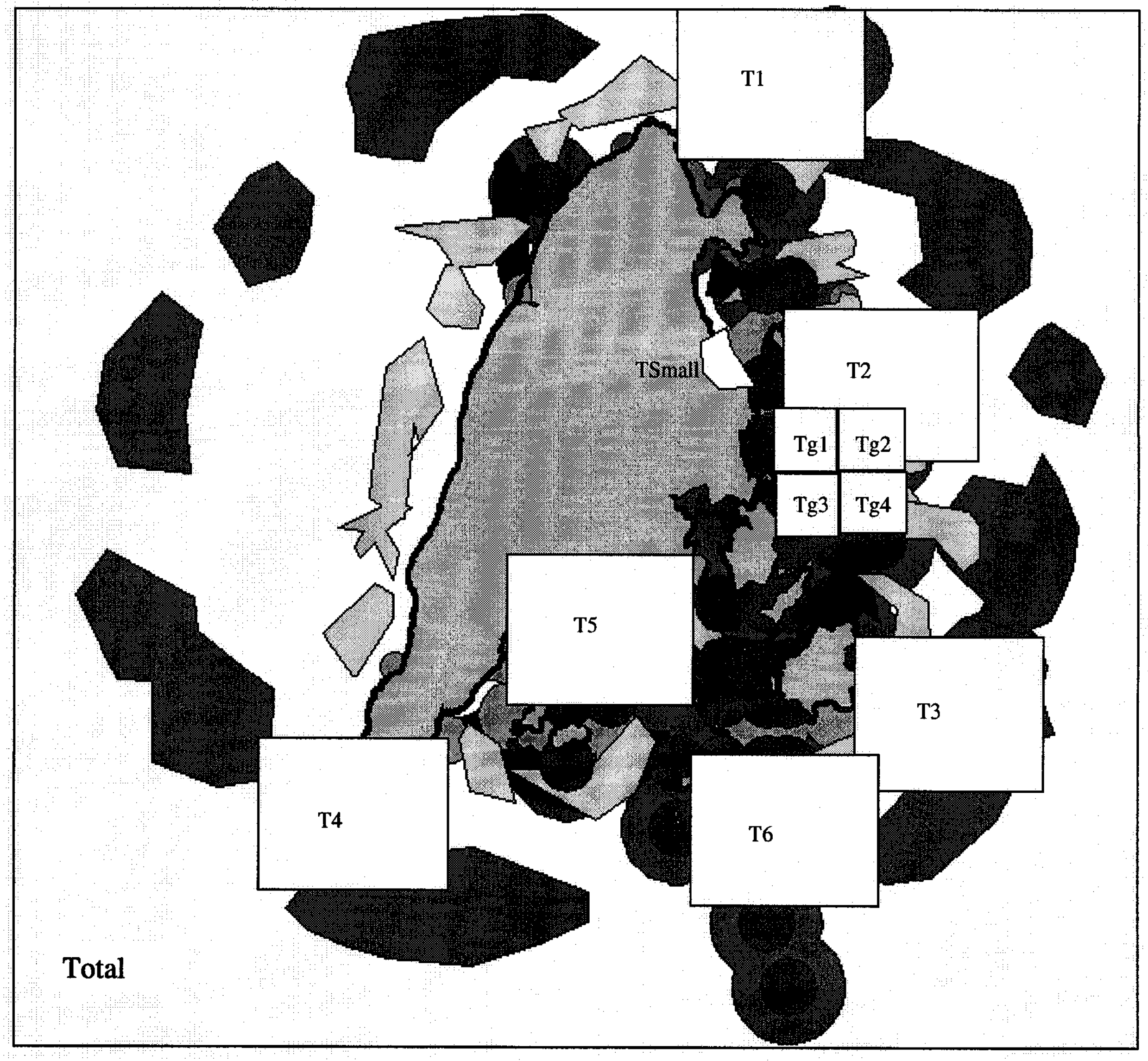


Figure 4-17 Map showing the overlaps and the Selected areas at examples used to search for the maximum and minimum yield values for overlaps.

In Table 4-9, T1, T2, T3, T4, T5, T6, TSmall, Tg1, Tg2, Tg3, Tg4, and Total are the names of the 12 selected areas showed in Figure 4-17. For each area, its yield values are listed in the corresponding row. The Maximums and Minimums of the 12 yield values are identified in the bottom rows of the table. For the sake of comparison, the unit yields are also listed in the table. In the next analysis, the maximum and minimum yield values are taken as the standards to standardize GIS outputs which are also the inputs of *Expert Choice 2000.*

Table 4-9 Searching for the maximum and minimum yield values in the study area

Name	YR Herring Day	YR Herring Night	YR Urchins	YH Rockweed	YH Salt Marshes	YT Chemical A	YA Herring Weirs	YA Fish Farms	YA Urchin Drags
T1	442.9	361.1	495.1	-2.0	0.0	0.0	11.2	0.0	95.0
T2	7.4	440.2	538.4	4.4	0.0	0.0	51.5	26.7	338.7
T3	360.2	372.1	540.4	3.3	0.0	0.0	9.4	1.8	156.0
T4	107.0	247.4	388.6	-0.9	0.0	0.0	0.0	1.3	77.9
T5	0.0	536.2	739.0	21.8	0.0	0.0	0.0	278.9	506.8
T6	37.2	448.3	708.4	14.9	0.0	0.0	0.0	3.4	452.9
TSmall	0.0	0.0	704.2	101.7	147.8	0.0	0.0	193.3	101.7
Tg1	0.0	28.3	391.2	49.2	0.0	5.0	0.0	194.3	668.0
Tg2	0.0	945.1	1156.1	0.6	0.0	0.0	0.0	0.0	965.0
Tg3	0.0	-1.6	-516.2	22.8	0.0	1513.5	0.0	412.0	516.8
Tg4	0.0	1593.7	1389.2	13.8	0.0	682.1	335.2	168.2	463.2
Total	126.5	222.3	248.6	7.8	0.4	173.6	26.7	36.0	147.5
Max	442.9	1593.7	1389.2	101.7	147.8	1513.5	335.2	412.0	965.0
Min	0.0	-1.6	-516.2	-2.0	0.0	0.0	0.0	0.0	77.9
Unit Yield	750.0	1511.0	988.0	350.0	551.0	1501.0	1121.0	26.0	249.0

4.2.2 Comparison of one selected area to the "ideal"

In Table 4-9, the Maximums and Minimums represent the ideal situations in the study area. If there existed a special area which concentrated all maximum yield values, except Chemical A took the minimum, to itself, this area could be named as "Ideal" area. By comparing with the "Ideal", it is possible to find the comparatively absolute ranking position for any selected area.

Take T2 as one of the selected areas (Figure 4-17) to compare it with the "Ideal".

According to Table 4-9, the vector constituted by the 17 yield values is:

(HD, HN, LB, SC, UR, RW, SM, CF, BS, CA, CB, CC, HW, FF, LT, SD, UD)

where the abbreviations are explained in Table 4-8.

For area T2, the vector is:

(7.4, 440.2, 0.0, 0.0, 538.4, 4.4, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 51.5, 26.7, 0.0, 0.0, 338.7)

where some zero values which are not given in Table 4-9 are added.

For the "Ideal", the vector is:

(442.9, 1593.7, 0.0, 0.0, 1389.2, 101.7, 147.8, 0.0, 0.0, 0.0, 0.0, 0.0, 335.2, 412.0, 0.0, 0.0, 965.0)

where the yield value of Chemical A is taken as 0.0, some zero values which are not given in Table 4-9 are added.

Now using Maximum and Minimum to standardize the vectors of T2 and the "Ideal" and put them into the Data Grid of *Expert Choice 2000*, the evaluations of the 5 participating groups are obtained and shown in Table 4-10 and Figure 4-18.

It is clear that except NGO and Local Communities, other groups evaluate site T2 is not as satisfied as half of the "Ideal". The general images of site T2 for the 5 Participating Groups are NGO (34%) greater than Local Communities (32.1%) greater than Provincial Governments (21.2%) greater than Federal Scientists (20.9%) greater than Industrial Organizations (13.4%). The average ranking of site T2 is 24.3%.

Table 4-10 Evaluations of the difference between a selected area and the "Ideal" attributed to the 5 participating groups

	Local Communities (LC)	**Federal Scientists (FS)**	**Industrial Organizations (IO)**	**Non-Government Organizations (NGO)**	**Provincial Government (PG)**
Site T2	0.321	0.209	0.134	0.34	0.212
The "Ideal"	0.679	0.791	0.866	0.666	0.788

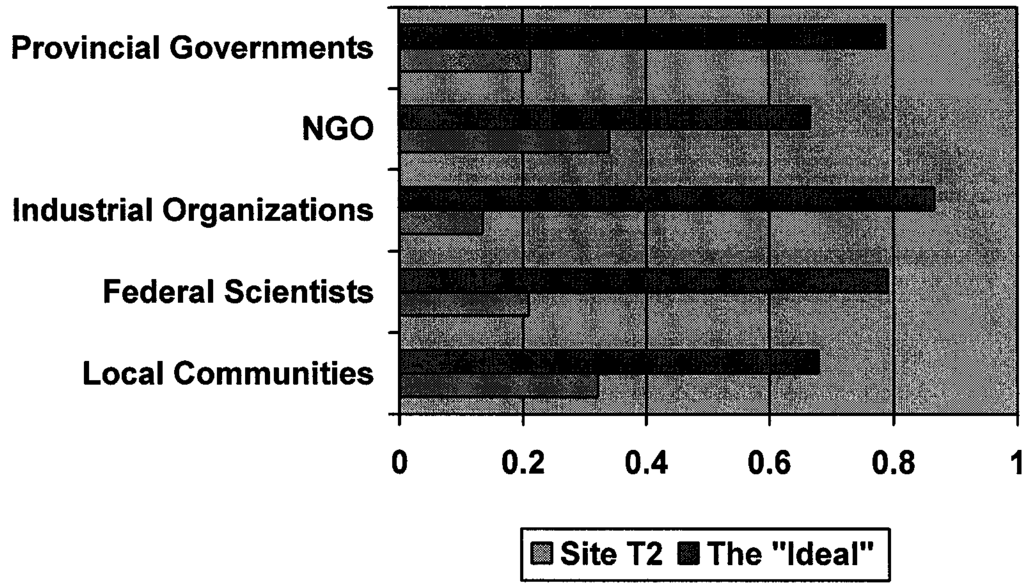


Figure 4-18 Evaluation summary of the Participating Groups in comparing the site T2 and the "Ideal"

4.2.3 Comparison of two selected areas

This experiment includes two cases: (1) comparison of two areas of approximately equal size; and (2) comparison of two areas that are of unequal size by area.

(1) Two areas of approximately equal size

Firstly, two equal size rectangular areas T2 and T3 are compared as illustrated in Figure 4-17 below. According to the information extracted from these two areas by the GIS model (Table 9-1, Table 9-2), some components with higher yields in area T2 have smaller yields in area T3 and vice versa (Table 4-9).

If it is assumed initially that each component has equal weight, then based on Table 4-9, simply summing all yields in area T2 will return a value of 51250 and in area T3, a value 51943. If the

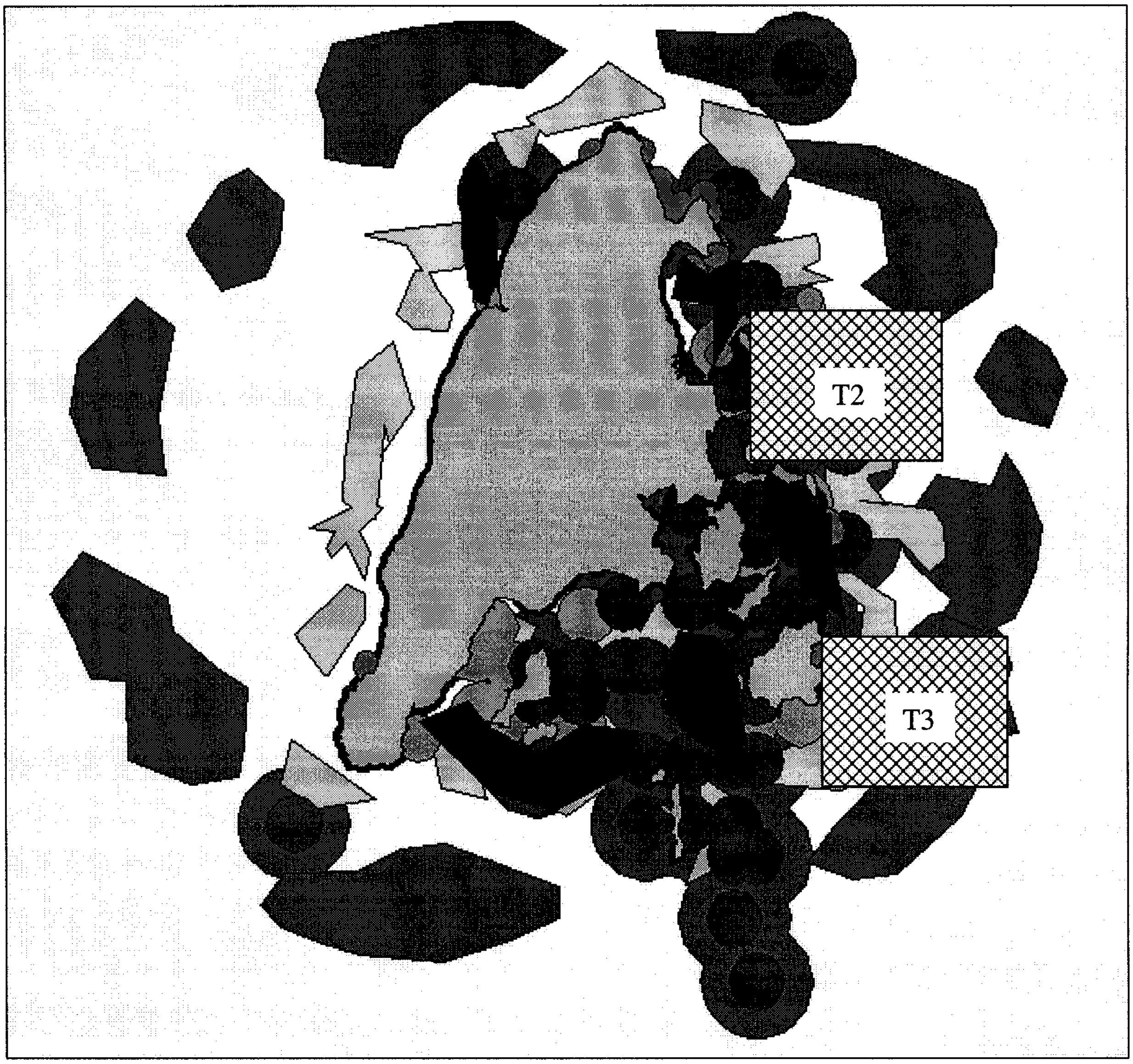


Figure 4-19 Two selected areas T2 and T3 of approximately equal size

unit yield per square kilometre is considered, the values of T2 and T3 are 1407 and 1443 respectively. These values have the same ranking as the total area as expected given the same approximate sizes of these different areas. From a strict valuation perspective, site T3 can be considered to be a more highly valued and preferable site than site T2 since 51943 > 51250 or 1443 > 1407. Generally, this simple valuation is not appropriate since it does not incorporate the relative importance of the different components or the interpretation of this importance by the key decision making participants. If these factors are taken into account, each component may have quite different weights and these weights may be with totally different value for different decision participants. In this part of the analysis *Expert Choice 2000* plays an important role.

Using the different AHP models established previously for the 5 participating groups, the rankings of the two areas for each of the groups are obtained using *Expert Choice 2000*. These results are summarized in Table 4-11 and the corresponding graph, Figure 4-20 below.

Table 4-11 Evaluations of two equal size sites attributed to the five participating groups

	Local Communities (LC)	**Federal Scientists (FS)**	**Industrial Organizations (IO)**	**Non-Government Organizations (NGO)**	**Provincial Government (PG)**
Site T2	0.512	0.450	0.652	0.501	0.687
Site T3	0.488	0.550	0.384	0.499	0.313

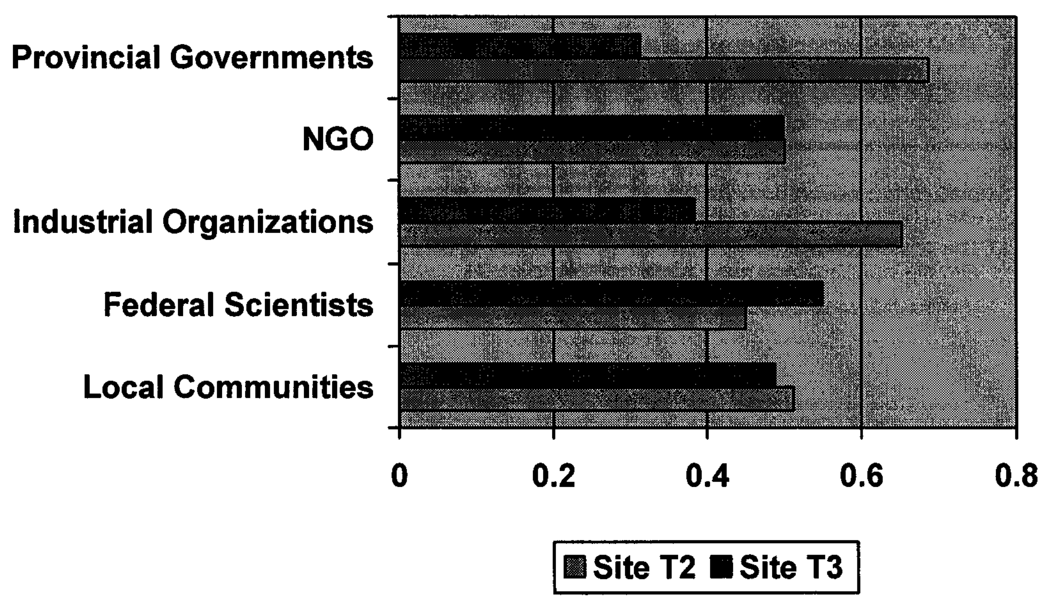


Figure 4-20 Evaluation summary of the Participating Groups in comparing the equal area sites T2 and T3

The above results demonstrate that the Provincial Government, NGOs, Industrial Organizations and Local Communities attribute more value to Site T2 than Site T3 although the differences vary among groups. On the contrary, Federal Scientists evaluate Site T2 as less valuable compared to Site T3. The difference is 10% (T2-45%; T3-55%). Generally speaking, Site T2 is closer to mainland Grand Manan than Site T3; Site T2 is an area in which more beneficial layers of Resources and Habitat can overlap. If pollution and overexploitation activities are avoided, it is expected to be a more profitable site than site T3 and thereby enhancing the value of Site T2 for these interested groups. However, the Federal Scientists, by virtue of their attributed weights are prone to consider the future value of Site T3 over the current value of Site T2.

Clearly, the divergence on the value ranking of T2 and T3 will cause some conflicts among the decision makers. However, it is important to notice the divergence and to balance the interests of each of the different related groups.

(2) Two areas of unequal size

The applications of this prototype model are not limited to compare equal or approximately equal size sites. When sites to be compared are unequal in size areas, their yields per unit area in each site are directly comparable. Therefore, the same process is applied as before using yields per unit area to conduct the comparisons. The following example illustrates this approach.

In this experiment, site T2, is used as before in the previous equal area size comparison. The second, smaller site is denoted as Site TSmall is located on the island coastline half way down the eastern side of the Island. Site TSmall is covered by more different layers than Site T2 (Appendix Table 9-3) and is shown in Figure 4-21 below along with Site T2. Site TSmall is an area of extensive beaches, mud flats, and shores including an area of salt marshes (the only such area documented in the data for Grand Manan); near the shallower marine area known as Dutch Ledge on the mainland side of Long Island.

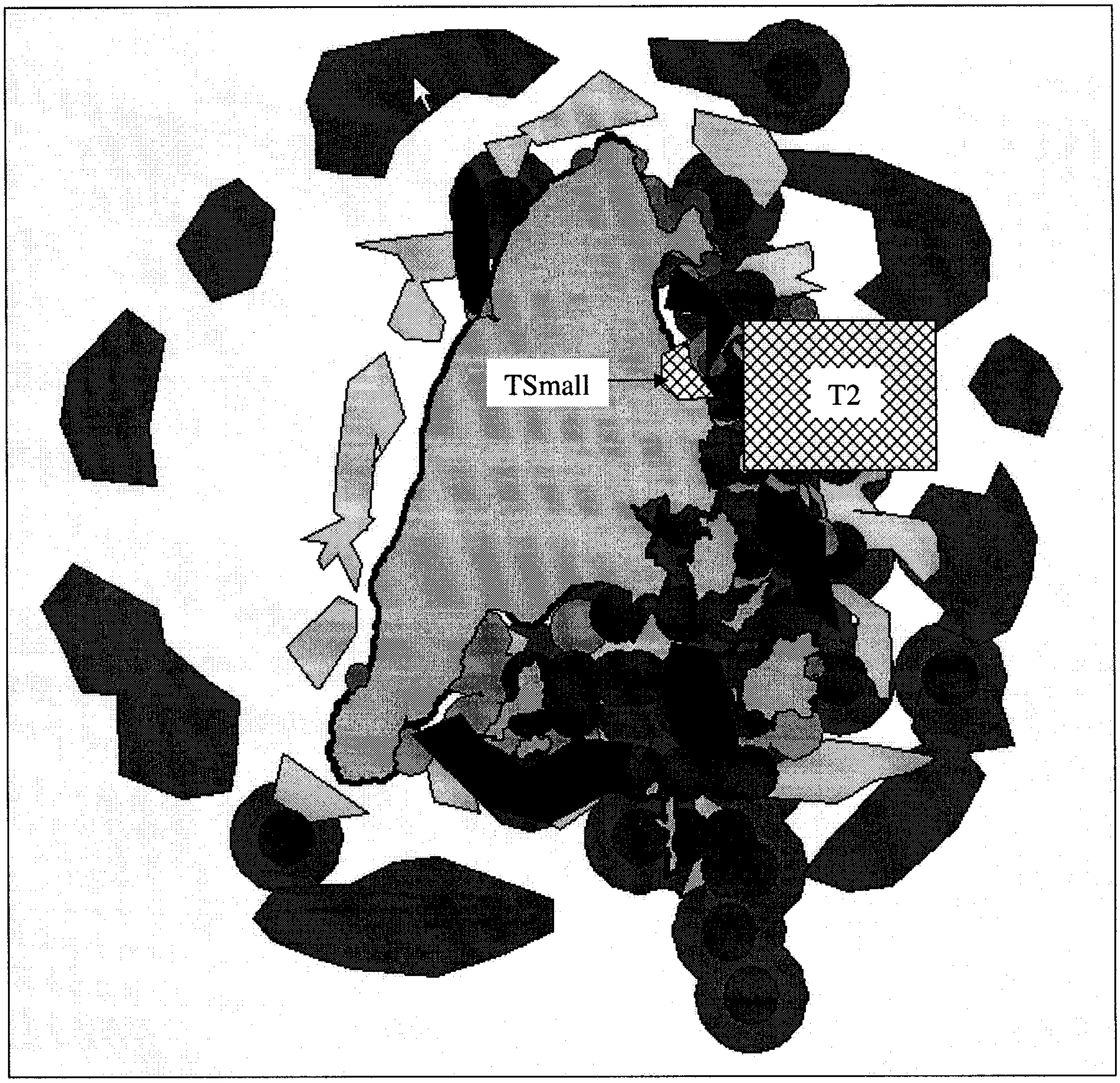


Figure 4-21 Two selected areas T2 and TSmall of unequal size

Site TSmall corresponds to the line denoted as TSmall in Table 4-8. Its yield summation of the different layers with equal weight is valued at 1249. This valuation is clearly smaller than the value attributed to site T2, 1407. However, if different weights are assigned to different layers and overlapping effects are taken into account, then the comparative results for these sites are completely different. The *Expert Choice 2000* results for the rankings by the 5 different participant groups for the two unequal size sites are showed in Table 4-12 and also illustrated graphically in Figure 4-22. It is not surprising that the smaller Site TSmall is evaluated as being more important than the larger Site T2 based on the attributed weights of the Provincial Government, NGOs, Industrial Organizations and Local Communities. Only Federal Scientists conclude an opposing answer.

Table 4-12 Evaluations of two unequal size sites T2 and TSmall attributed to the five participating groups

	Local Communities (LC)	**Federal Scientists (FS)**	**Industrial Organizations (IO)**	**Non-Government Organizations (NGO)**	**Provincial Government (PG)**
Site T2	0.407	0.601	0.475	0.464	0.496
Site TSmall	0.593	0.399	0.525	0.536	0.504

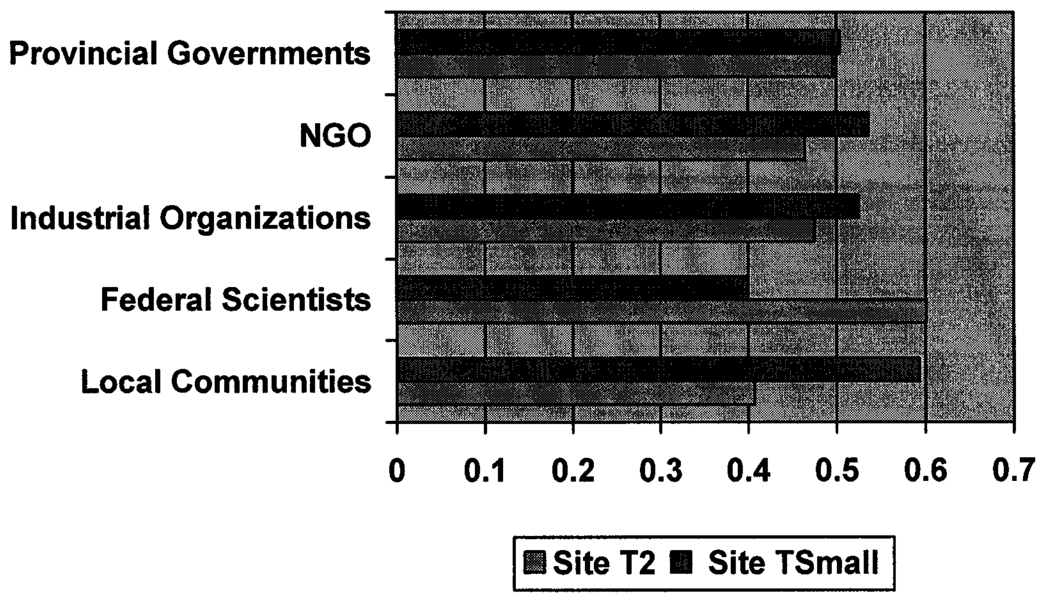


Figure 4-22 Evaluation summary of the Participating Groups in comparing the unequal area sites T2 and TSmall

Again, the ranking result of Site T2 and TSmall shows the divergence between federal scientists and other interest groups. The divergence results from the weights attributed to different components including Resources, Habitat, Toxicology and Activities as well as the subcomponents of each component. It is noticed that federal scientists think a lot of the harmoniousness between mankind and the natural world and do not pay much attention to the current profits. For example, they assign component Resources very high weights; they have predilection for subcomponent Herring Weirs because this kind of activity does not cause big damage for environments. The comparison result of Site T2 and TSmall shows that Site T2 contains more layers that federal scientists prefer and it is more valuable in a foresighted viewpoint. It is the duty of decision makers to negotiate different groups to make a compromise developing policy.

4.2.4 Site evaluation for a group of candidates

(1) Best site selection from a group of alternative sites

A more general and complicated comparison is to select the "best" (i.e., most highly evaluated) site from among a set of alternative sites. The alternative sites may be of quite different sizes and shapes and would therefore require a unit are yield analysis. Multiple alternative sites may consist of two, three or more sites and these sites may be concentrated in a small area or dispersed throughout a large region. Figure 4-23 shows 4 sites chosen in this experiment. The 4 sites are denoted as G1, G2, G3 and G4 corresponding to Tg1, Tg2, Tg3 and Tg4 in the Table of 4-8 above. All these sites are concentrated in the vicinity of Great Duck Island, a small island close to Grand Manan about halfway down the eastern shore. The purpose of this experiment is to show how the model can be used to distinguish among sites in close proximity in an area that is currently being perceived as a potential new area for aquaculture licensing.

Figure 4-23 Map of four selected areas concentrated in the vicinity of Great Duck Island Sound

In the evaluation, independent of the number of sites and how their shapes and sizes are distributed, the process is the same as comparing two sites. That is, first these sites are designated in the background and the corresponding information extracted. Next, send the information to *Expert Choice 2000* using participants' different models to do the ranking and comparison.

The chosen 4 sites in this experiment all have the same area and are distributed one by one around Great Duck Island. Actually, they are divided areas in one big area. Their simple summed yields of assumed equal weights for the different layers are G1 = 1336, G2 = 3067, G3 = 1947 and G4 = 4645 separately. While G4 has the highest simple yield rating, it is not correct to conclude that site G4 is the "best" one among the four alternatives. Next table, Table 4-13 and graph, Figure 4-24 show the *Expert Choice 2000* results for this evaluation problem.

Table 4-13 Evaluations of the 4 Duck Island Sound sites attributed to the five participating groups

	Local Communities (LC)	Federal Scientists (FS)	Industrial Organizations (IO)	Non-Government Organizations (NGO)	Provincial Government (PG)
Site G1	0.339	0.258	0.289	0.324	0.279
Site G2	0.289	0.305	0.199	0.302	0.254
Site G3	0.108	0.083	0.215	0.116	0.222
Site G4	0.264	0.354	0.297	0.258	0.245

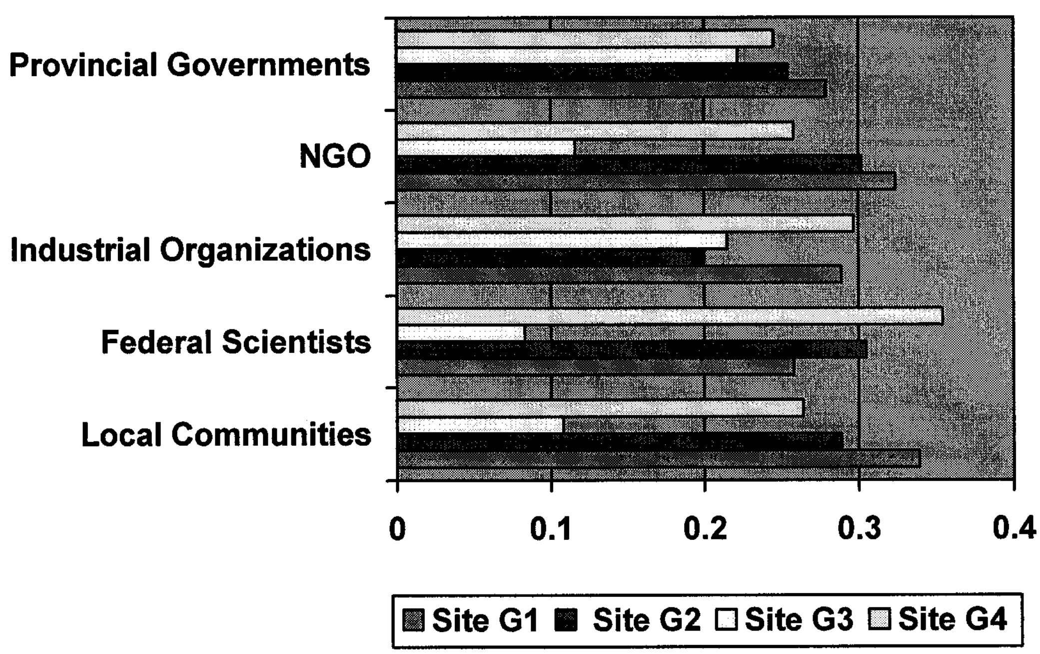


Figure 4-24 Evaluation summary of the Participating Groups in comparing the four sites: G1, G2, G3 and G4 in Duck Island Sound.

What is obvious from the results for this case is that Site G3 has lower relative ranking by every participating group. Checking its location in Figure 4-23, the conclusion may be the result of Site G3 overlapping with the Chemical A plume that decreases its overall value. Site G2 is also not the "best" candidate site since it does not occupy a "first place" ranking by any participating group. That leaves possible "best" alternatives between Site G1 and Site G4. Four of five participating groups including the Provincial Government, NGOs, Industrial Organizations and Local Communities attributed the highest score to Site G1. Only one group, Federal Scientists, evaluate G4 ahead of G1. The possible reason may be that even though G4 is also overlapped by Chemical A, the overlapped part is not too big to cover the benefit of overlapping with subcomponent Herring Weir (0.38), to which Federal Scientists give very high weight. On the other hand, G1 is covered largely by Urchin Drags and received only Federal Scientists' weight of 0.04. From a long-term perspective, G4 seems better G1; but combining current interests, G1 can be considered as the best candidate. Of course, the ultimate selection will be made by the governance group acting on consensus.

(2) The impact of assigning a fish farm within a specific area

If a fish farm is established somewhere in a specific area, it will definitely affect the original yields evaluations in this existing area. At the same time, new harvesting through the fish farm activity may complement the expected decrease in other layer yields in the same area. Therefore the combined total effect for such changes may be positive or negative for the area and requires careful evaluation.

Using the model developed here, the affect of running an aquafarm can be evaluated by comparing related data obtained before and after running the inclusion of the aquafarm. For the 4 divided areas G1, G2, G3 and G4 around Duck Island Sound, the original data already contain the influence of fish farm sites and these are captured in the corresponding evaluations obtained in the previous experiment. Thus, this experiment compares selected areas with and without fish farms by removing the existing fish farms ones from those already in the 4 areas previously evaluated. These areas are re-evaluated and compared with the evaluation results from the previous analysis to check the impact on total yields to judge the real effects of having established fish farm in these areas.

Table 4-14 shows the evaluation results of the 5 different participant groups for the 4 divided areas as before (G1, G2, G3 and G4). Figure 4-25 contains the same data in the corresponding histogram graph form.

It is noted that the industrial organizations and federal scientists more strongly give Site G4 with farms top positions. NGOs and Local Community groups however, keep G1 in the first position. A significant change occurs for Provincial Government: they rank Site G2 as the most important site without fish farms to replace the original preferred Site G1 selection with fish farms.

Generally, the overall comparisons of the 4 sites with and without fish farms show some changes in ranking positions. This result may be dependent on the status of fish farms in the corresponding sites. Figure 4-23 shows that G2 is almost not covered by fish farms; therefore its final value is not influenced much by setting or not setting fish farms. G3 is with the biggest covering ratio of fish farms in the 4 sites. However, because it is also largely covered by

Table 4-14 Evaluations of the 4 sites around Great Duck Island (with fish farm sites removed)

	Local Communities (LC)	**Federal Scientists (FS)**	**Industrial Organizations (IO)**	**Non-Government Organizations (NGO)**	**Provincial Government (PG)**
Site G1	0.335	0.234	0.232	0.323	0.276
Site G2	0.291	0.287	0.255	0.295	0.308
Site G3	0.110	0.087	0.102	0.106	0.129
Site G4	0.265	0.392	0.411	0.276	0.287

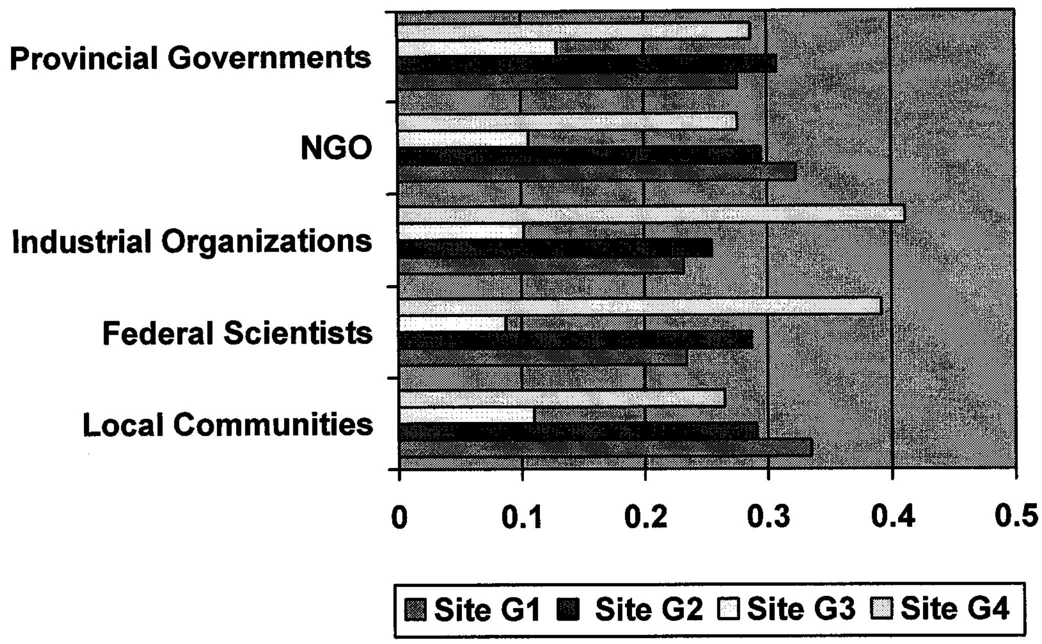


Figure 4-25 Evaluation summary of the Participating Groups in comparing the four sites with fish farms removed: G1, G2, G3 and G4 in Duck Island Sound.

Chemical A, the final value changing before and after setting fish farms is not very big. The obvious change should occur at G1 and G4. Compare Figure 4-24 and Figure 4-25, it is easy to find that without fish farms, Industrial Organizations totally change their ranks for G1 and G4, G4 is ranked higher than G1; Scientists stress their stands further by increasing the value of G4 from 0.354 to 0.392.

For further analysis, let us look at Figure 4-26, an enlarged map for the Site G1. The G1 site is a rectangle with area 5.2 km^2 and located to the northwest of Great Duck Island. Before removing the fish farm site in this area, there are total 28 different layer compositions (Appendix Table 9-4) and produce a simple summed yield of 1326 (referring to the Tg1 line in Table 4-9, where the yield of Chemical A is considered as minus); By removing the fish farm in this site, the number of layer compositions decreases to 16 (Appendix Table 9-5) and the total simple yield sum is surprisingly increased (not decreased) to 1424 with the removal of the fish farm. The following table (Table 4-15) and graph (Figure 4-27) show the results of the *Expert Choice 2000* analysis for the different participant groups.

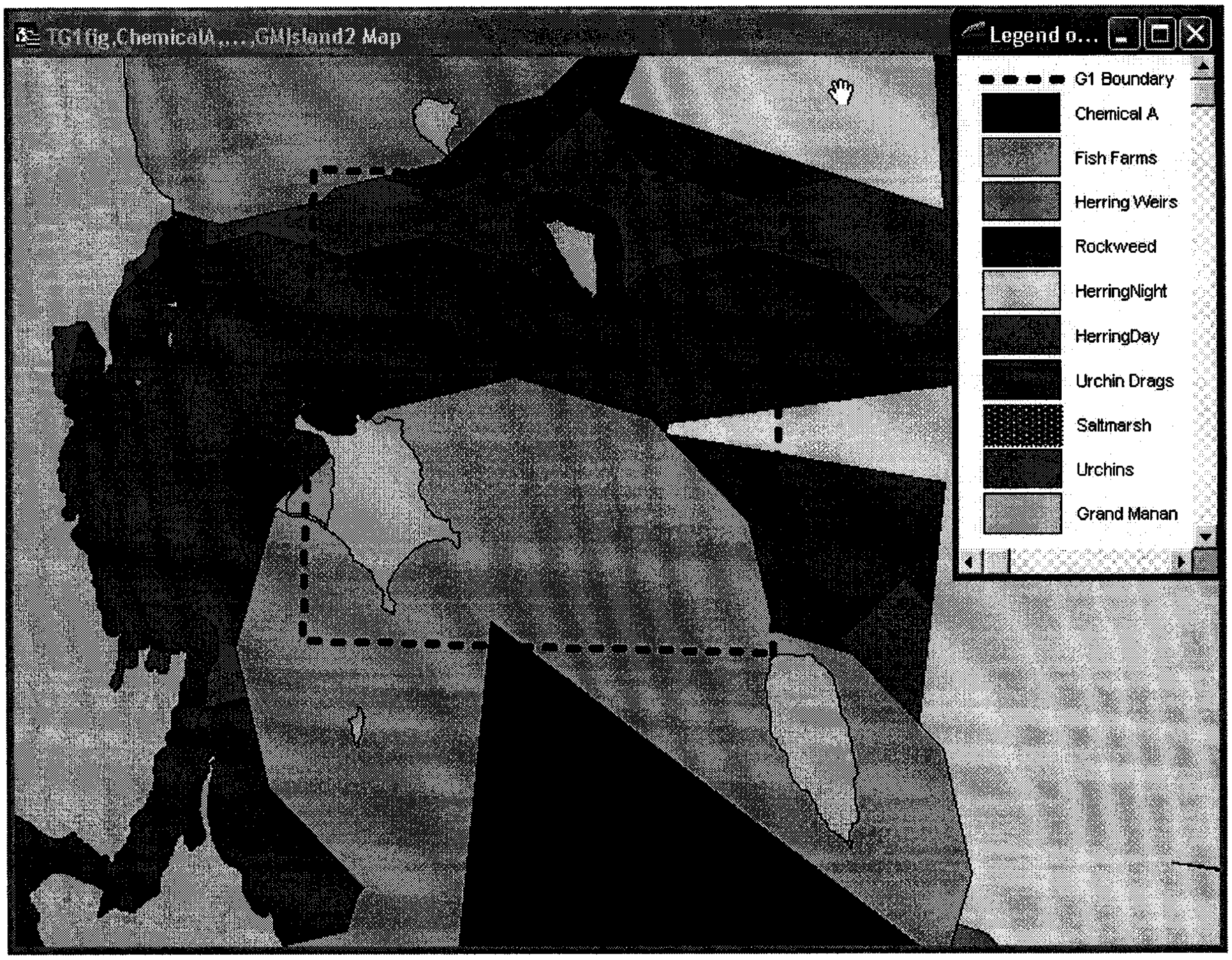


Figure 4-26 The enlarged area of Site G1 in which the effect of setting fish farm will be removed

The conclusion is that if Site G1 includes a fish farm, its total yield as evaluated by the 5 participating groups is generally not evaluated as being smaller than without the fish farm. Among of them, only Federal Scientists are suspected to evaluate sites without fish farms higher than those with a fish farm, at least for this particular case. Otherwise, it would appear that fish farm valuation in G1 is basically not opposed from a valuation perspective by the different participants.

Table 4-15 Evaluations of Site G1 with and without a fish farm

	Local Communities (LC)	Federal Scientists (FS)	Industrial Organizations (IO)	Non-Government Organizations (NGO)	Provincial Government (PG)
Site G1 with Fish Farms	0.501	0.492	0.574	0.500	0.646
Site G1 without Fish Farms	0.499	0.508	0.426	0.500	0.354

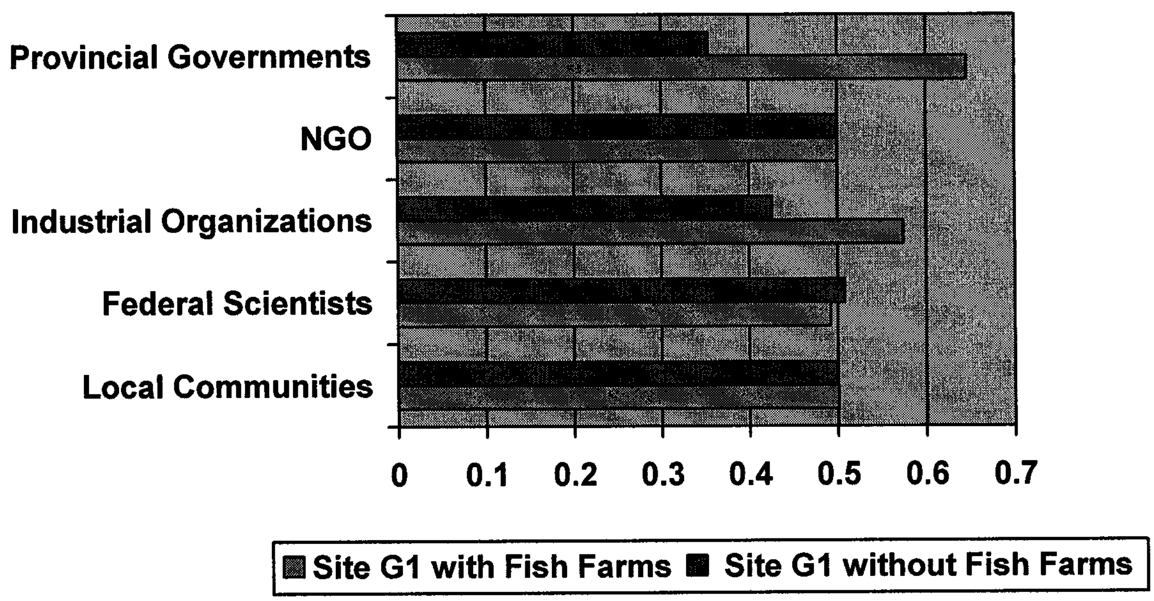


Figure 4-27 Evaluation summary of the Participating Groups in comparing the Site G1 in Duck Island Sound with and without a Fish Farm

5 CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE WORK

5.1 Conclusions

The rapid development of coastal aquaculture in recent years has shown much growth and promise for developing and developed productivity of marine resources (Fletcher and Neyrey, 2003). At the same time, the negative impacts caused by inefficiencies in running aquaculture farms are also becoming more and more prominent. These problems have included marine disease spread, the illicit use of drugs, protein requirements exceeding output, and the effects of fish farms on the surrounding ecosystem from water-borne toxins. How to decrease these impacts and ensure sustainable development is a problem for decision makers in aquaculture. This thesis is trying to touch this field from the point of view of the area of systems science and decision theory and provide decision makers with a feasible DSS. It is a test work in progress with the advantage of having had first hand contact with the Department of Fisheries and Oceans and the Province of New Brunswick who are both keenly interested in the systems integration idea to aid decision making in this complex environment. To respond to the four research objectives proposed in the introduction part, the conclusions of the thesis can be summarized as below:

(1) It is important to notice that in making aquaculture site evaluations and in providing viable, systemic alternatives for decision makers involves many aspects.

Following the suggestions and modelling summarized here by DFO scientists concerned with coastal aquaculture at the St. Andrews Biological Station, the impacts of running coastal aquaculture are classified into two categories: impacts on the natural ecosystem side and impacts on the human social side. For the natural ecosystem, the model presented in this research divides into 4 components - Resources, Habitat, Toxicology and Activities. According to the real situation of Grand Manan Island, the 4 components are further subdivided into 17 subcomponent items. They are:

- Herring Day, Herring Night, Lobster, Scallops and Urchins for Resources;
- Rockweed, Salt Marshes, Current Flow and Bottom Structure for Habitat;
- Chemical A, Chemical B and Chemical C for Toxicology;
- Herring Weirs, Fish Farms, Lobster Traps, Scallop Drags and Urchin Drags for Activities.

For human social consideration, the model explicitly takes into account the considerable decision contributions of Local Communities, NGOs, Industrial Organizations, Federal Scientists and Provincial Governments. These 5 participants are designed to cover the various key interest groups who are implicated in the aquaculture decision process.

(2) GIS and AHP are effective tools to summarize and disseminate "natural" and "human" information related to coastal aquaculture

Maps, graphs, tables or database are effective tools to integrate various data. GIS embraces all of these tools and provides corresponding operation methods. The disadvantage of applying GIS is its complicated operations. In this research, developed DSS is a GIS-based application. MapInfo is controlled by VB.Net, using MapInfo's Object Linking and Embedding, this DSS simplifies complicated operations and designs friendly interfaces oriented users who are not familiar with trivial and complicated GIS operations. The whole analysis and operating process for coastal aquaculture problems are customized. Producing output results of various evaluations and ranking of areas from data uploading as well as area selection is a simple, direct and visual general procedure.

Hierarchical structure is also a very effective way to organize various data. In this research, the Analytic Hierarchy Process (AHP) is adopted to deal with the 4 natural components and their 17 subcomponents as well as the GIS output results. Utilizing AHP's software *Expert Choice 2000*, the 5 participants or "stakeholders" can easily pairwise compare different components, items as well as the output results, and finally obtain the comprehensive evaluation.

(3) Development of a prototype DSS using AHP and GIS

GIS is a powerful tool for managing spatially referenced data and AHP is an efficient tool for multicriteria decision making in these environments. The perfect combination of the two tools is the direction taken toward developing the DSS. It is difficult to totally embed AHP to GIS software and a realistic method is to integrate the two tools. In this research, the developed DSS combines MapInfo (GIS software) and *Expert Choice 2000* (AHP software) by easily triggering *Expert Choice 2000* and sending necessary data or parameters to it through an invisible background to the user by applying VB.Net. Generally, the developed DSS contains a hierarchical model, which is established by current available data, and perspectives of the 5 participants or "stakeholders". Decision makers can open a graphic interface and select any interesting area on the background map to extract related information which includes the tendencies of different "stakeholders".

(4) Coastal aquaculture around Grand Manan Island is an epitome of view for the farming of specific species in the Bay of Fundy region of Atlantic Canada.

In this research, several specific cases of selected areas are chosen to be evaluated. These areas include the total study area, two equal sized areas, two unequal sized areas and a group of subdivided areas including and excluding fish farms. For the whole study area, the extracted results accounts for the entire inventory around the Grand Manan Island. These results contain various values of corresponding hierarchical components or subcomponents which form the rough image of coastal aquaculture around Grand Manan Island. In addition, other special experiments can provide detailed evaluations for specific area. All these delineate a general view of the fish farming and other marine activities around Grand Manan Island. However, limited to the available data, the image cannot be similarly extended beyond the localized Grand Manan Island area. In order to get an integrated view for the farming of specific species in the Bay of Fundy, more data and further study are required.

To sum up, this research developed a simple DSS which integrates GIS and AHP. Applying this DSS to Grand Manan Island shows that it is helpful for decision makers. However, it is necessary to keep in mind that this research is only a very beginning attempt. As a promising DSS, a lot of improving work should be followed.

5.2 Recommendations / Extensions

This study aims to provide an integrating method to support coastal aquaculture decision making. The primary applying the developed model to Grand Manan Island shows that the effort on data integrating and interface integrating are on the right way. Therefore it is worthwhile to improve the acquired results and go further ahead in the same direction. At least, the next 5 aspects can be pursued.

(1) Construct a more complete database of natural and human system components for describing ongoing information that pertain to situations involving aquaculture policies and decisions. These data are needed for almost all related parts in this study and to make the process and model a workable system for use in actual decision making. Specifically, the following detailed distribution data and characteristic data list is provided as a critique of the current provide database:

Resources

- Herring: staging area, juvenile inshore area
- Lobster: molting area, feeding area
- Scallops: population area
- Urchins: more detailed population area

Habitat

- Rockweed: distribution area, bloom period, healthy or not
- Salt marshes: light or heavy? species need it
- Bottom structure: mud? sandy? flat or deep?
- Currents flow: high tide, low tide, post-storm tides

Toxicology

- Chemical A: weak, moderate or strong, location and area?
- Chemical B: weak, moderate or strong, location and area?
- Chemical C: weak, moderate or strong, location and area?

Activities

- Herring weirs: small weir, average or large weirs, harvest
- Lobster traps: wooden trap, wire trap or other, location and harvest
- Urchin dragging: less than 35', 45' or 65', location and harvest
- Scallop dragging: less than 35', 45' or 65', location and harvest
- Fish farms: low input cap, medium or high input cap, size and harvest

(2) Find more appropriate measurement and evaluation methods for different components

Even though some distributions and characteristics of different components are known, it is still difficult to evaluate their real and comparative values in the coastal aquaculture. In this study, all components of Resources, Habitat, Toxicology and Activities are loosely determined by the unified "$" or money value concept so that they may be considered directly comparable. However, some components are not easily quantified in this way, for example, component rockweed and chemical A. A reasonable consideration is that knowing more about the dependence of different species to the habitat, more meaningful evaluation could be made for the habitat. Similarly, if more information regarding the affects of specific pollution to the environment is known, then more accurate estimates for this pollution would be made.

(3) Find more effective means of incorporating related participants in the decision making evaluation process

Full participation by groups will assist in diminishing the negative impacts of operating coastal aquaculture on society. In this study, AHP is adopted to evaluate different ideas from Federal Scientists, NGOs, Local Communities, Industrial Organizations and Provincial Government groups. As an effective method of multicriteria evaluation, AHP is with many advantages including easy use, ability to adopt and summarize different criteria to one system, available software production – *Expert Choice 2000* etc. However, it is also with some disadvantages. For example, AHP is mainly dependent on the hierarchical structure and subjective pairwise comparison results. If the hierarchical structure is changed or the pairwise comparison results are altered (both of them are not unique), the final result may change significantly. In addition, if there are many levels in the decision hierarchy, the number of pairwise comparisons will become quite extensive and the total process will be very time-consuming and tedious (DeSteiguer, et al., 2002). AHP is a good method but not the only one to do multicriteria evaluation. On the other hand, expending or reselecting different groups or "stakeholders" to be the players or participants is also necessary.

(4) Expand the study area from Grand Manan Island to the whole Bay of Fundy

Grand Manan Island is a comparatively isolated area. Its aquafarm size and commercial activity scale are relatively small given the considerable activity elsewhere in the Bay of Fundy on the New Brunswick side. The species types and affected aspects of running aquaculture are limited to a relatively small range of values. Therefore it is different from the situation in the whole Bay of Fundy, a much larger area. However, this study mainly stresses the model development, the operational methodology and capabilities to solve the possible impacts of interest from operating aquaculture sites. From a modelling perspective, it is easy to increase the numbers of components, and to encompass more evaluation factors or enlarge the evaluating participants.

(5) Refine the operation interface and update it to the Internet

The future of GIS-based applications as developed here is to customize its interface. As mentioned in the text, the decision makers need simple, direct and easily operated interfaces to do their specialized work. In this study, the main framework or interface is a result of designing the system with this specific intention re aquaculture evaluation in mind. It is much easier to run the fully integrated model than using the original software. However, it is always not enough. Besides improving its functions, increasing its speed and decreasing its difficulty of maintenance, a significant step is to update this program from Windows project to a Web project, that is, to allow users run it via the Internet. In that case, potential users in different areas can control the same program, exchange mutual ideas and update it freely.

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7 Appendix I – Data Integration of MapInfo

MapInfo is a GIS application. All related information, whether textual or graphic, is organized in the form of tables and each table is a group of MapInfo files that constitute either a map file or a database file (MapInfo 2002a). In other words, a table will have the following two files:
(1) FileName.tab: a small text file describing the format of the file containing the data; and
(2) FileName.dat or FileName.wks, FileName.dbf, FileName.xls: containing the tabular data.

To display tables in the Map window, the used data must contain graphic objects or X and Y (longitude and latitude) coordinates. Assigning these coordinates is called geocoding. Once the X and Y coordinates are assigned to the used data records, the table will also contain graphic objects and there will be two more files associated with the table:
(3) FileName.map: used to describe the graphic objects.
(4) FileName.id: a cross-reference file that links the data with the objects.

Generally, only the *.tab file is provided to users to carry out operations. In another words, users only need to manipulate the *.tab file.

Figure 7-1 shows the data records of fish farm sites around Grand Manan Island in the standard MapInfo main interface that contains the operational manual buttons and a window for dealing with map, table or other data. Different symbols and colours can be selected to mark the uploaded and geocoded points. Here a star symbol and a red/dark colour are used to represent the fish farm sites. Its corresponding table (data source) is also shown on the screen as presented in Figure 7-1. The table is named "GMsites.tab" and can be found on the top of the table window. In the table of Figure 7-1, columns B and C denote the North latitude and Eastern longitude for each farm site. The table structure is editable, i.e., the column name and its corresponding data type (character, binary, float etc.) can be set freely. Clearly, this allows the table to incorporate different information to the figure.

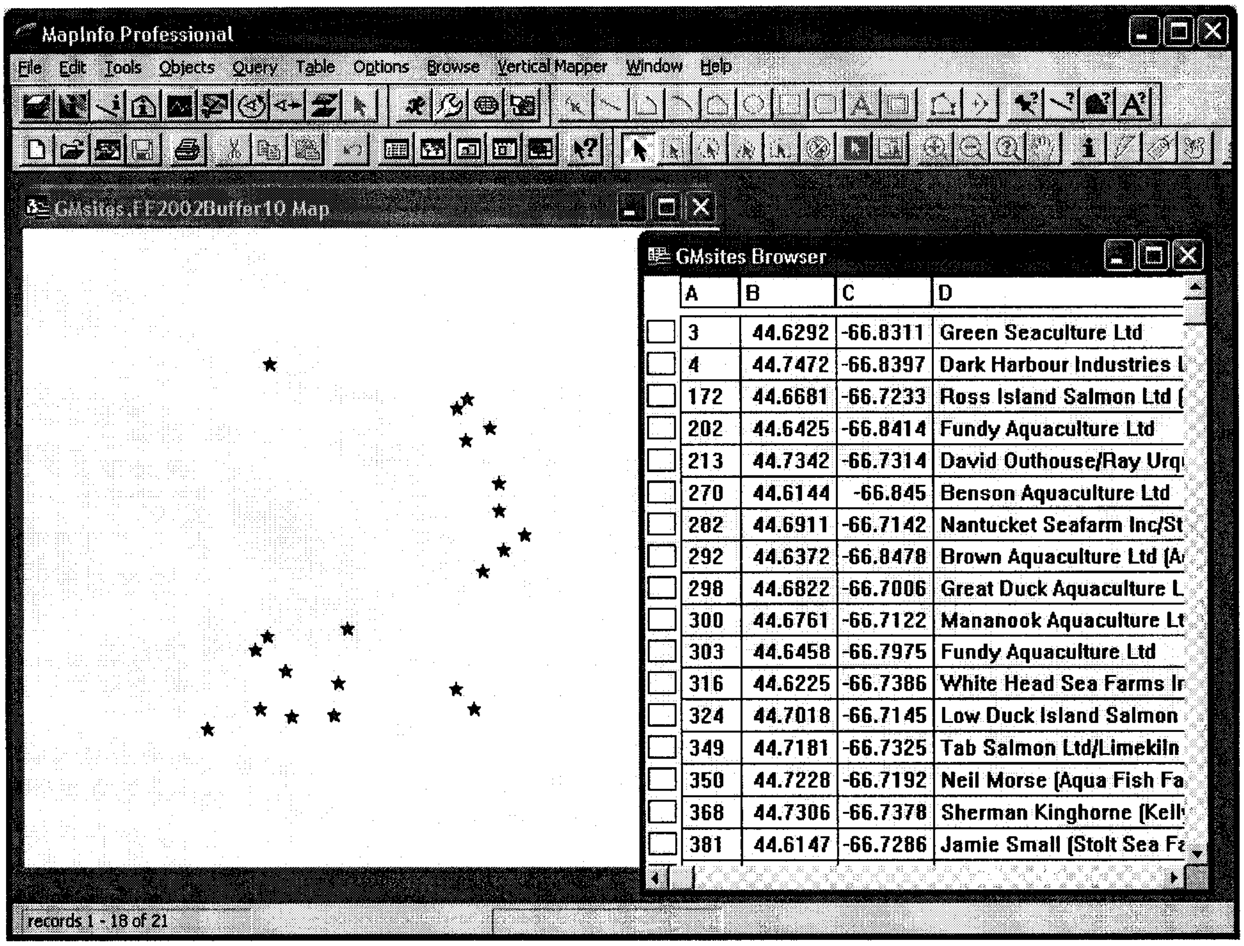

Figure 7-1 MapInfo window with geocoded sites in the GMSites Browser table for fish farms around (invisible) Grand Manan Island

In MapInfo, the figure and the table are inseparable. Different pieces or elements in the figure correspond to different lines in the table, i.e., altering the table results in a comparable alteration to the figure. Therefore, users are free to select the figure window or the table window to perform different operations. For example, to move figure pieces or to change shapes using the figure window is convenient, however, if one is selecting elements with some specific characteristics, then using the table window and corresponding SQL (write out) sentence will be more convenient.

Figure 7-2 shows the overlapping result of fish farm sites with the island of Grand Manan map and its adjacent marine areas, where this study is applied. In Figure 7-2, a Layer Control window is also displayed. This window is used to show the layered map information added in the map figure window. It can be used to add or remove map layers, to adjust layered overlap order, to set layer editable status and to change layer colour or type, etc.

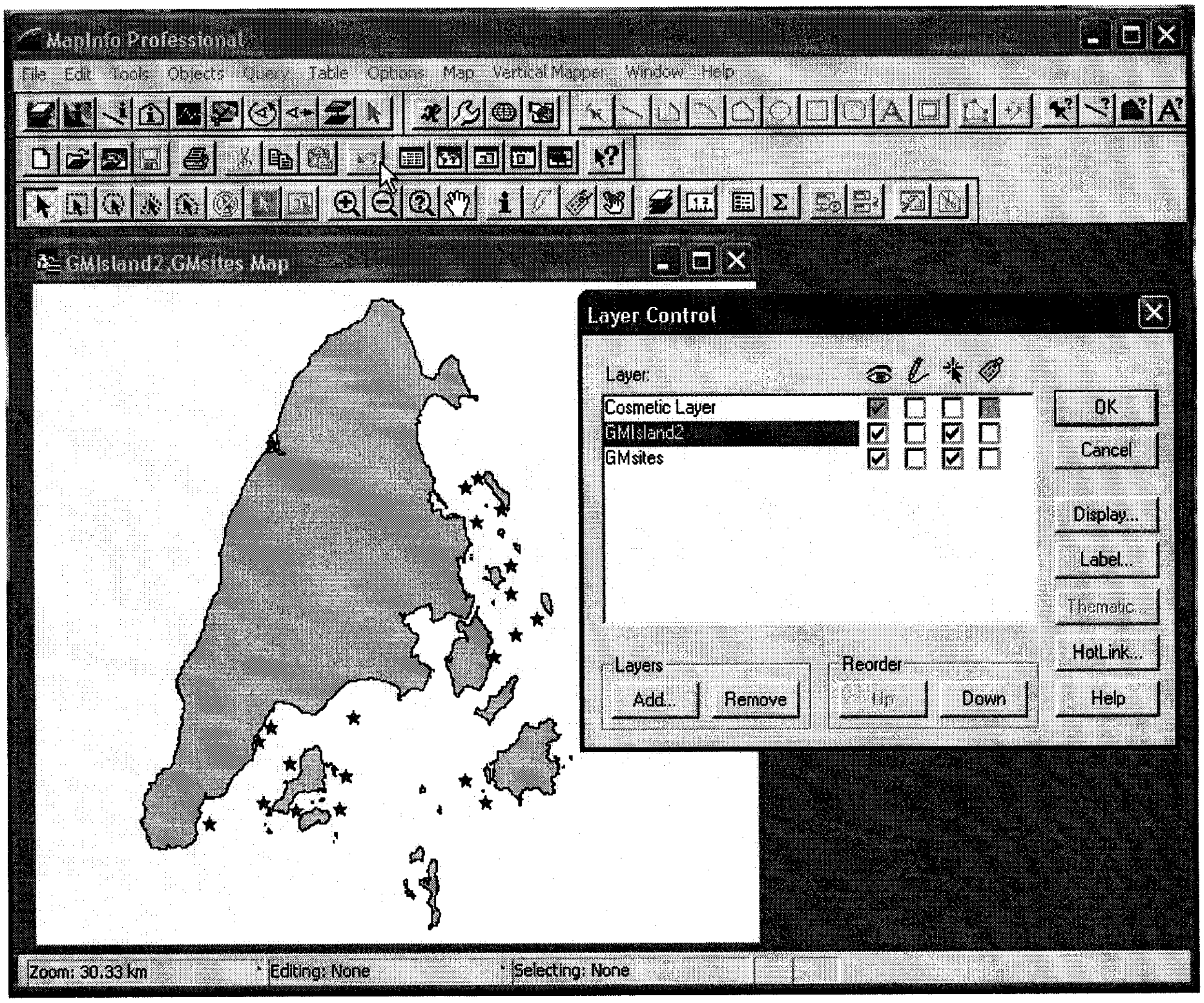

Figure 7-2 MapInfo window with geocoded sites for fish farms around visible Grand Manan Island layer; the Layer Control shows the situation of layered map data

From the Layer Control window, it is easy to find that except for the Cosmetic Layer, there are two layers overlapped in the figure window. The two layers are GMIsland2 and GMsites. Since they are seamlessly overlapped, they cannot be separated from the base map and the fish farm distribution on the map window. In other words, the data, which are from the Grand Manan

Island table and from the fish farm table, are precisely integrated. In the same way, many map layers can be overlapped.

MapInfo provides tools to select specific areas and then to extract all selected data (whether overlapped or not) in that area. Among them, Set Target Editing Model allows users to set a map object as the target for editing, then create a modifying object that will act as the "cookie cutter" that overlays the target and performs the editing action on the target (MapInfo 2002b).

Consider a simple example from Figure 7-2, that extracts the fish farm sites in a specific area. The main process can be described stepwise as follows:

(1) Designate the specific area

This is done by opening the Layer Control window, setting the Cosmetic Layer as editable, and then using MapInfo's drawing tools to delineate the specific area. The drawing tools can be used to draw a polygon, a rectangular, an ellipse or other basic figure elements. Here, the polygon tool is used to designate a polygon as the specific area that is selected for further analysis.

(2) Set the fish farm layer as the Target layer

This is done by first making the layer of fish farm sites editable in the Layer Control window; then, selecting the whole layer of fish farm sites by using the select function of the Query button or, alternatively, by clicking all sites one by one using the shift key and left mouse button simultaneously. Next, set the selected layer as the Target layer by pushing Ctrl and T key at the same time or using the Object dropdown menu and selecting "Set Target" as noted in Figure 7-3.

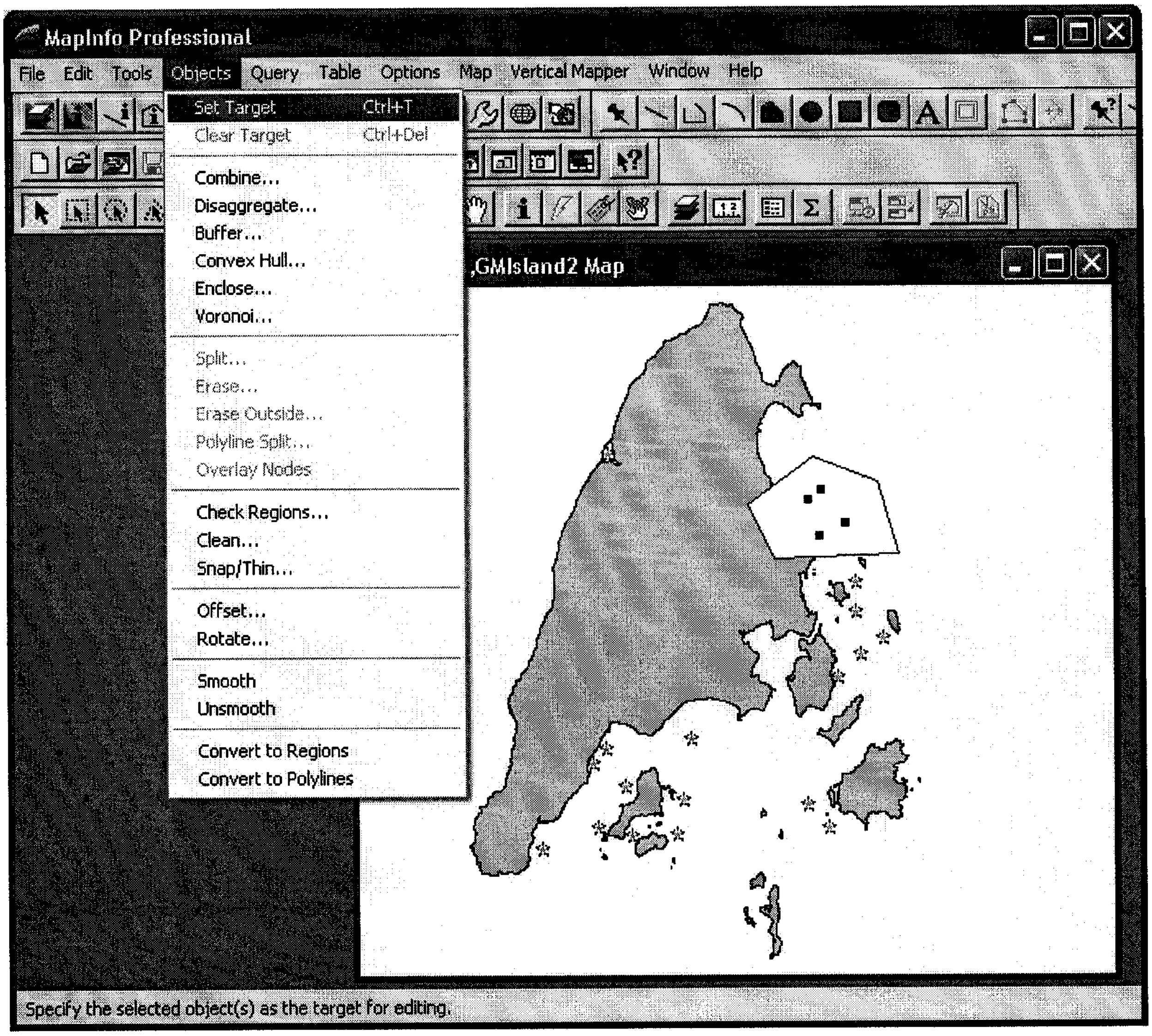

Figure 7-3 MapInfo window that sets the fish farm layer as the target layer; note that the designated polygon are selected contains 4 fish farm sites

(3) Perform the edit operation

The edit operation includes the Combine, Split, Erase, Erase Outside, or Overlay function nodes. In this example, the Erase Outside function will be used. Firstly, select the designated polygon in the Map window to be the cutter object; secondly, choose dropdown mean Object > Erase Outside, and the Data Disaggregation dialog displays (as in Figure 7-4); thirdly, choose the disaggregation method as “Value” for each field in the Destination list; finally, click OK will erase the part outside the designated polygon as shown in Figure 7-4.

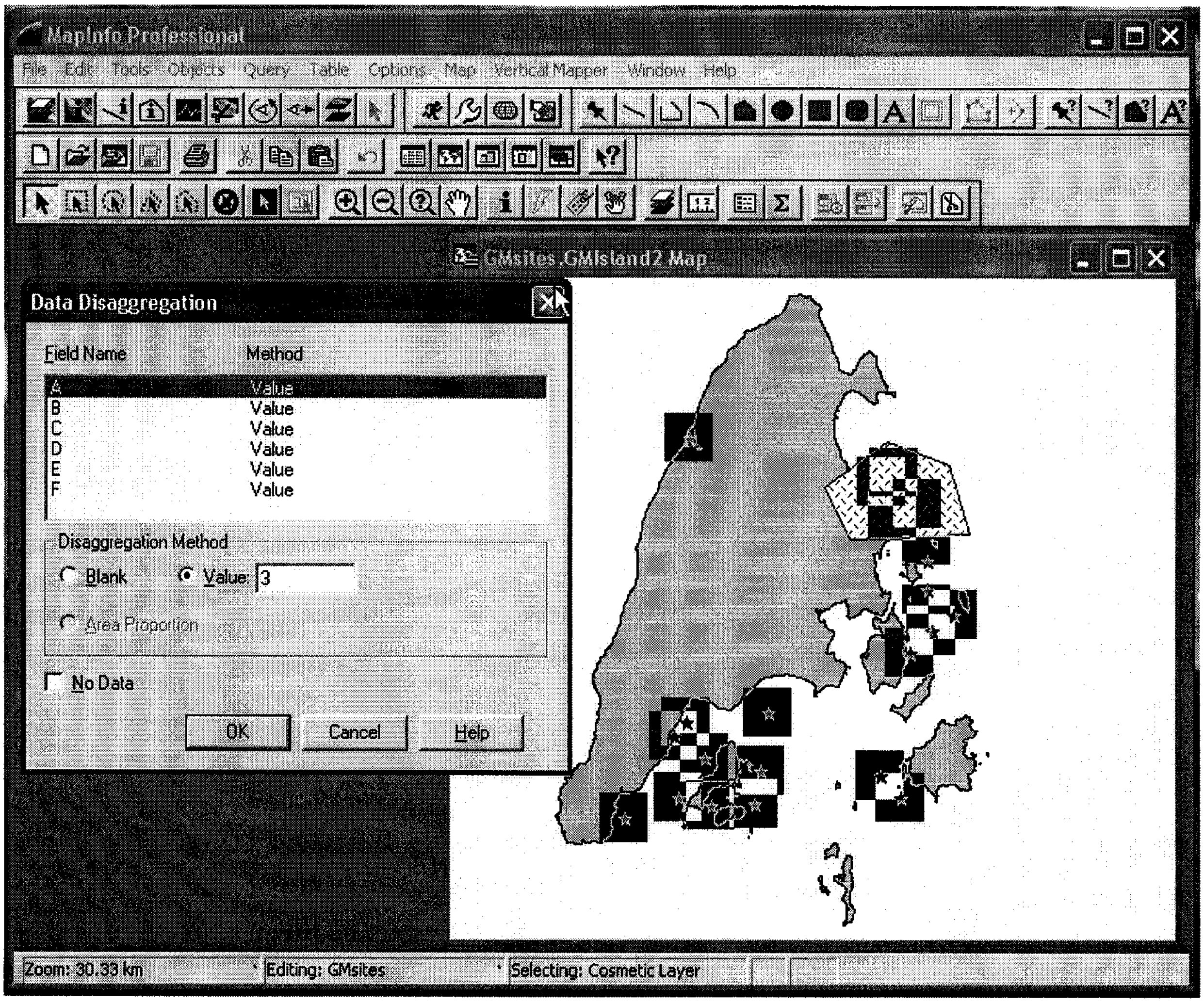

Figure 7-4 MapInfo window showing the Erase Outside function to extract the data in the designated polygon

The final result of the extracted area of interest is presented in Figure 7-5. The 4 fish farm sites and their corresponding table of GMsites, including 4 lines, demonstrate that the extraction is successful.

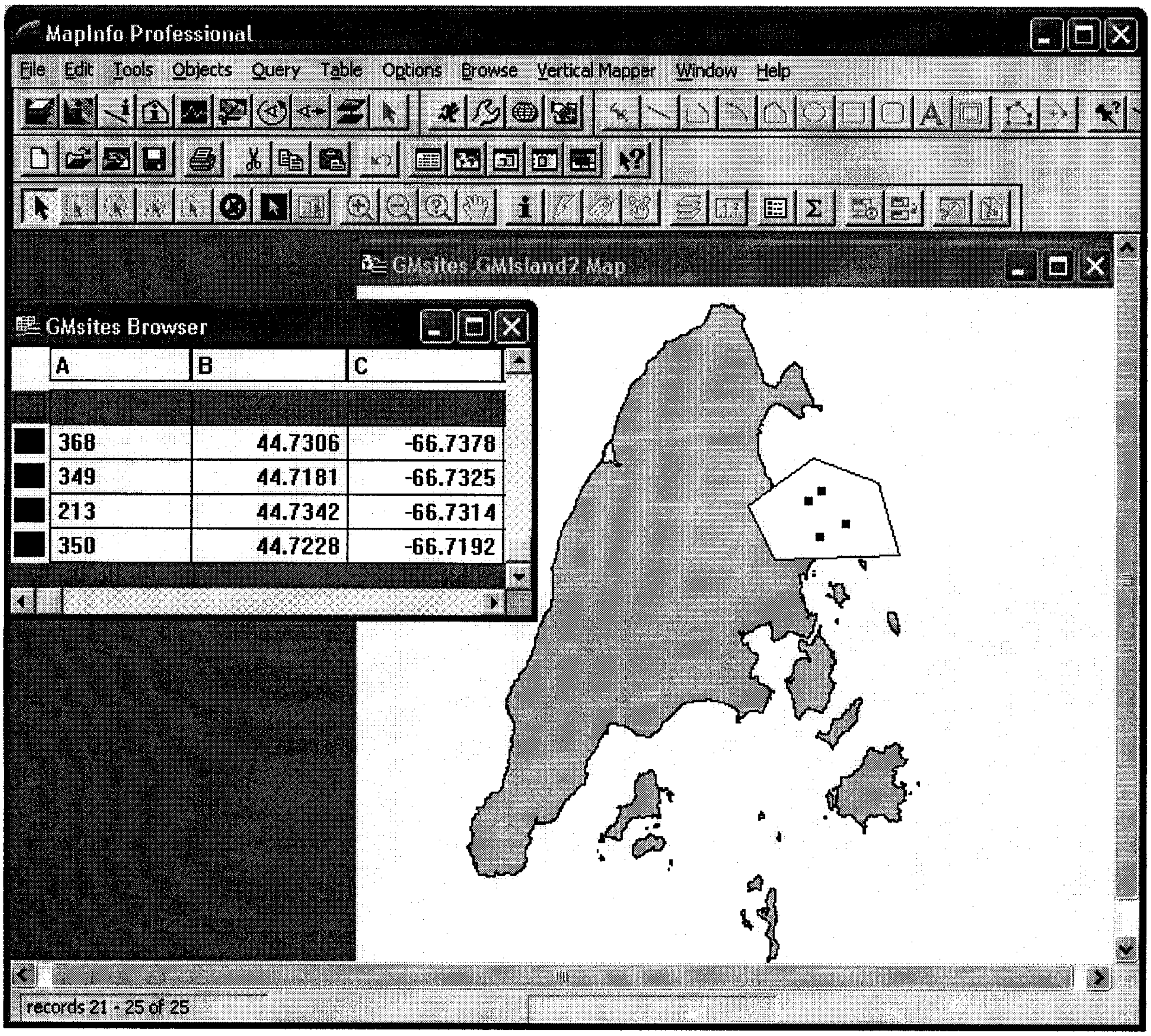

Figure 7-5 MapInfo window of extracted fish farm sites in the selected polygon area

8 Appendix II – Input of Pairwise Comparison

Comparison tables of the relative importance of rowwise components to columnwise components with respect to different Goals. The Goals are achieving greatest value for a selected marine area, achieving optimal values for the yields of Resources, Habitat, Toxicology and Activities. The rowwise and columnwise components are 17 subcomponent items of the 4 natural components. They are:

(1) Herring Day, Herring Night, Lobster, Scallops and Urchins for Resources;

(2) Rockweed, Salt Marshes, Current Flow and Bottom Structure for Habitat;

(3) Chemical A, Chemical B and Chemical C for Toxicology; and

(4) Herring Weirs, Fish Farms, Lobster Traps, Scallop Drags and Urchin Drags for Activities

The tables correspond to the component pairwise comparisons attributed to different decision making groups; they are:

- Local communities,
- Federal Scientists,
- Industrial Organizations,
- Non Governmental Organizations as well as
- Provincial Governments.

A 9-point scale is used to describe the binary comparison trade-offs for all pairwise comparisons. The meaning of the scale items is as described in Table 3-5.

(1) Equal

(2) Equal to Moderate

(3) Moderate

(4) Moderate to Strong

(5) Strong

(6) Strong to Very Strong

(7) Very Strong

(8) Very Strong to Extreme

(9) Extreme

The inconsistent coefficients are also included.

(1) Local communities

Table 8-1 Comparison table of the relative importance of rowwise components to columnwise components with respect to the Goal of achieving greatest value for a selected marine area (Incon: 0.07)

	Resources	Habitat	Toxicology	Activities
Resources		0.5	0.2	2
Habitat			1	2
Toxicology				3
Activities				

Table 8-2 Comparison table of the relative importance of rowwise Resource subcomponents to columnwise Resource subcomponents with respect to the Goal of achieving greatest value for a selected marine area (Incon: 0.00)

	Herring Day	Herring Night	Lobster	Scallops	Urchins
Herring Day		1	1	1	1
Herring Night			1	1	1
Lobster				1	1
Scallops					1
Urchins					

Table 8-3 Comparison table of the relative importance of rowwise Habitat subcomponents to columnwise Habitat subcomponents with respect to the Goal of achieving greatest value for a selected marine area (Incon: 0.02)

	Rockweed	Salt Marshes	Current Flow	Bottom Structure
Rockweed		0.5	2	4
Salt Marshes			3	5
Current Flow				1
Bottom Structure				

Table 8-4 Comparison table of the relative importance of rowwise Toxicology subcomponents to columnwise Toxicology subcomponents with respect to the Goal of achieving greatest value for a selected marine area (Incon: 0.05)

	Chemical A	Chemical B	Chemical C
Chemical A		4	6
Chemical B			3
Chemical C			

Table 8-5 Comparison table of the relative importance of rowwise Activities subcomponents to columnwise Activities subcomponents with respect to the Goal of achieving greatest value for a selected marine area (Incon: 0.00)

	Herring Weirs	Fish Farms	Lobster Traps	Scallop drags	Urchin drags
Herring Weirs		1	0.5	0.5	1
Fish Farms			0.5	0.5	1
Lobster Traps				1	3
Scallop drags					2
Urchin drags					

(2) Industrial Organizations

Table 8-6 Comparison table of the relative importance of rowwise components to columnwise components with respect to the Goal of achieving greatest value for a selected marine area (Incon: 0.04)

	Resources	Habitat	Toxicology	Activities
Resources		3	3	1/3
Habitat			2	1/4
Toxicology				1/5
Activities				

Table 8-7 Comparison table of the relative importance of rowwise Resource subcomponents to columnwise Resource subcomponents with respect to the Goal of achieving greatest value for a selected marine area (Incon: 0.06)

	Herring Day	Herring Night	Lobster	Scallops	Urchins
Herring Day		1	1/5	1/7	3
Herring Night			1/5	1/7	3
Lobster				1/3	5
Scallops					7
Urchins					

Table 8-8 Comparison table of the relative importance of rowwise Habitat subcomponents to columnwise Habitat subcomponents with respect to the Goal of achieving greatest value for a selected marine area (Incon: 0.00)

	Rockweed	Salt Marshes	Current Flow	Bottom Structure
Rockweed		3	3	1
Salt Marshes			1	1/3
Current Flow				1/3
Bottom Structure				

Table 8-9 Comparison table of the relative importance of rowwise Toxicology subcomponents to columnwise Toxicology subcomponents with respect to the Goal of achieving greatest value for a selected marine area (Incon: 0.05)

	Chemical A	Chemical B	Chemical C
Chemical A		4	6
Chemical B			3
Chemical C			

Table 8-10 Comparison table of the relative importance of rowwise Activities subcomponents to columnwise Activities subcomponents with respect to the Goal of achieving greatest value for a selected marine area (Incon: 0.06)

	Herring Weirs	Fish Farms	Lobster Traps	Scallop drags	Urchin drags
Herring Weirs		1/2	1/3	1/5	3
Fish Farms			1/3	1/5	7
Lobster Traps				1/2	5
Scallop drags					7
Urchin drags					

(3) Non Governmental Organizations (NGO)

Table 8-11 Comparison table of the relative importance of rowwise components to columnwise components with respect to the Goal of achieving greatest value for a selected marine area (Incon: 0.00)

	Resources	Habitat	Toxicology	Activities
Resources		1	1/2	3
Habitat			1/2	3
Toxicology				5
Activities				

Table 8-12 Comparison table of the relative importance of rowwise Resource subcomponents to columnwise Resource subcomponents with respect to the Goal of achieving greatest value for a selected marine area (Incon: 0.00)

	Herring Day	Herring Night	Lobster	Scallops	Urchins
Herring Day		1	1	1	1
Herring Night			1	1	1
Lobster				1	1
Scallops					1
Urchins					

Table 8-13 Comparison table of the relative importance of rowwise Habitat subcomponents to columnwise Habitat subcomponents with respect to the Goal of achieving greatest value for a selected marine area (Incon: 0.00)

	Rockweed	Salt Marshes	Current Flow	Bottom Structure
Rockweed		1	3	3
Salt Marshes			3	3
Current Flow				1
Bottom Structure				

Table 8-14 Comparison table of the relative importance of rowwise Toxicology subcomponents to columnwise Toxicology subcomponents with respect to the Goal of achieving greatest value for a selected marine area (Incon: 0.05)

	Chemical A	Chemical B	Chemical C
Chemical A		4	6
Chemical B			3
Chemical C			

Table 8-15 Comparison table of the relative importance of rowwise Activities subcomponents to columnwise Activities subcomponents with respect to the Goal of achieving greatest value for a selected marine area (Incon: 0.00)

	Herring Weirs	Fish Farms	Lobster Traps	Scallop drags	Urchin drags
Herring Weirs		1	1	1	1
Fish Farms			1	1	1
Lobster Traps				1	1
Scallop drags					1
Urchin drags					

(4) Provincial Governments

Table 8-16 Comparison table of the relative importance of rowwise components to columnwise components with respect to the Goal of achieving greatest value for a selected marine area (Incon: 0.08)

	Resources	Habitat	Toxicology	Activities
Resources		3	2	1/4
Habitat			1/3	1/5
Toxicology				1/2
Activities				

Table 8-17 Comparison table of the relative importance of rowwise Resource subcomponents to columnwise Resource subcomponents with respect to the Goal of achieving greatest value for a selected marine area (Incon: 0.02)

	Herring Day	Herring Night	Lobster	Scallops	Urchins
Herring Day		1	1/3	1/3	1/2
Herring Night			1/3	1/3	1/2
Lobster				1	3
Scallops					3
Urchins					

Table 8-18 Comparison table of the relative importance of rowwise Habitat subcomponents to columnwise Habitat subcomponents with respect to the Goal of achieving greatest value for a selected marine area (Incon: 0.06)

	Rockweed	Salt Marshes	Current Flow	Bottom Structure
Rockweed		1/2	3	2
Salt Marshes			2	3
Current Flow				2
Bottom Structure				

Table 8-19 Comparison table of the relative importance of rowwise Toxicology subcomponents to columnwise Toxicology subcomponents with respect to the Goal of achieving greatest value for a selected marine area (Incon: 0.05)

	Chemical A	Chemical B	Chemical C
Chemical A		4	6
Chemical B			3
Chemical C			

Table 8-20 Comparison table of the relative importance of rowwise Activities subcomponents to columnwise Activities subcomponents with respect to the Goal of achieving greatest value for a selected marine area (Incon: 0.01)

	Herring Weirs	Fish Farms	Lobster Traps	Scallop drags	Urchin drags
Herring Weirs		1/5	1/3	1/3	1/5
Fish Farms			2	2	2
Lobster Traps				1	1/2
Scallop drags					1/2
Urchin drags					

(5) Federal Scientists

Table 8-21 Comparison table of the relative importance of rowwise components to columnwise components with respect to the Goal of achieving greatest value for a selected marine area (Incon: 0.06)

	Resources	Habitat	Toxicology	Activities
Resources		4	3	5
Habitat			2	3
Toxicology				3
Activities				

Table 8-22 Comparison table of the relative importance of rowwise Resource subcomponents to columnwise Resource subcomponents with respect to the Goal of achieving greatest value for a selected marine area (Incon: 0.00)

	Herring Day	Herring Night	Lobster	Scallops	Urchins
Herring Day		1	1	1	1
Herring Night			1	1	1
Lobster				1	1
Scallops					1
Urchins					

Table 8-23 Comparison table of the relative importance of rowwise Habitat subcomponents to columnwise Habitat subcomponents with respect to the Goal of achieving greatest value for a selected marine area (Incon: 0.00)

	Rockweed	Salt Marshes	Current Flow	Bottom Structure
Rockweed		1	1	1
Salt Marshes			1	1
Current Flow				1
Bottom Structure				

Table 8-24 Comparison table of the relative importance of rowwise Toxicology subcomponents to columnwise Toxicology subcomponents with respect to the Goal of achieving greatest value for a selected marine area (Incon: 0.05)

	Chemical A	Chemical B	Chemical C
Chemical A		4	6
Chemical B			3
Chemical C			

Table 8-25 Comparison table of the relative importance of rowwise Activities subcomponents to columnwise Activities subcomponents with respect to the Goal of achieving greatest value for a selected marine area (Incon: 0.03)

	Herring Weirs	Fish Farms	Lobster Traps	Scallop drags	Urchin drags
Herring Weirs		3	1	5	7
Fish Farms			1/3	2	5
Lobster Traps				3	5
Scallop drags					3
Urchin drags					

9 Appendix III – Extracted Information from Different Areas

Extracted information of overlapping layers from the specific area is put in the table in this appendix, where the table columns are defined as follows:

- IDResources, IDHabitat, IDToxicology and IDActivities represent the indices of Resources, Habitat, Toxicology and Activities respectively
- YieldR, YieldH, YieldT and YieldA represent the corresponding Yields of Resources, Habitat, Toxicology and Activities in the specific overlapping layer of the selected area
- The Area column shows the total area corresponding to the ovelapping layers indicated by each line of the table. The first line in which all indexes are zero represents the total selected area in square kilometres, k^2.

The ID value definitions are as follows:

- IDResources:

  0 - Not present in the current overlapping area;

  1 - Herring resource abundance during Day-time aggregations;

  2 - Herring resource abundance during Night-time aggregations;

  3 – Lobster resource abundance;

  4 – Scallop resource abundance;

  5 – Urchin resource abundance.

- IDHabitat:

  0 - Not present in the current overlapping area;

  1 – Rockweed habitat present;

  2 - Salt Marshes habitat present;

  3 - Bottom Structure description, e.g., sandy, gravelly, etc.;

  4 - Current Flow description.

- IDToxicology:
  - 0 - Not present in the current overlapping area;
  - 1 - Chemical A (precise chemical to be identified here);
  - 2 - Chemical B (precise chemical to be identified here);
  - 3 - Chemical C (precise chemical to be identified here).

- IDActivities:
  - 0 - Not present in the current overlapping area;
  - 1 - Herring Weirs present;
  - 2 - Fish Farms present;
  - 3 - Lobster Traps present;
  - 4 - Scallop dragging area;
  - 5 – Urchin dragging area.

Two or more than two digital numbers in the same ID columns represent the overlaps of different subcomponents originating from the same component group. For example, IDResources = 21 means the overlap between Herring Night and Herring Day in the overlapping area.

Table 9-1 Extracted information from area T2

ID Resources	ID Habitat	ID Toxicology	ID Activities	Yield Resources	Yield Habitat	Yield Toxicology	Yield Activities	Area
0	0	0	0	0.0	0.0	0.0	0.0	36.4
0	0	0	5	0.0	0.0	0.0	2868.2	11.5
0	0	0	2	0.0	0.0	0.0	81.0	3.1
0	0	0	52	0.0	0.0	0.0	841.2	3.1
0	0	0	1	0.0	0.0	0.0	1510.4	1.3
0	0	0	51	0.0	0.0	0.0	1759.7	1.3
0	0	0	21	0.0	0.0	0.0	763.3	0.7
0	0	0	521	0.0	0.0	0.0	926.1	0.7
0	1	0	0	0.0	340.8	0.0	0.0	1.0
0	1	0	5	0.0	276.4	0.0	196.8	0.8
0	1	0	2	0.0	251.2	0.0	18.9	0.7
0	1	0	52	0.0	251.2	0.0	197.8	0.7
0	1	0	1	0.0	57.3	0.0	183.4	0.2
0	1	0	51	0.0	57.3	0.0	224.3	0.2
0	1	0	21	0.0	56.5	0.0	185.0	0.2
0	1	0	521	0.0	56.5	0.0	225.2	0.2
5	0	0	0	20573.7	0.0	0.0	0.0	20.8
5	0	0	5	11370.9	0.0	0.0	2868.3	11.5
5	0	0	2	3036.1	0.0	0.0	81.0	3.1
5	0	0	52	3016.0	0.0	0.0	841.2	3.1
5	0	0	1	1298.2	0.0	0.0	1471.7	1.3
5	0	0	51	1269.8	0.0	0.0	1759.7	1.3
5	0	0	21	657.8	0.0	0.0	763.3	0.7
5	0	0	521	655.6	0.0	0.0	926.1	0.7
5	1	0	0	962.1	340.8	0.0	0.0	1.0
5	1	0	5	780.2	276.4	0.0	196.8	0.8
5	1	0	2	709.2	251.2	0.0	18.9	0.7
5	1	0	52	709.2	251.2	0.0	197.8	0.7
5	1	0	1	161.8	57.3	0.0	183.4	0.2
5	1	0	51	161.8	57.3	0.0	224.3	0.2
5	1	0	21	159.4	56.5	0.0	185.0	0.2
5	1	0	521	159.4	56.5	0.0	225.2	0.2
2	0	0	0	11117.5	0.0	0.0	0.0	7.4
2	0	0	5	5853.4	0.0	0.0	965.4	3.9
2	0	0	1	142.7	0.0	0.0	105.8	0.1
2	0	0	51	71.5	0.0	0.0	64.8	0.0
52	0	0	0	16891.2	0.0	0.0	0.0	6.8
52	0	0	5	9680.4	0.0	0.0	965.4	3.9
52	0	0	1	149.7	0.0	0.0	67.1	0.1
52	0	0	51	118.2	0.0	0.0	64.8	0.0
1	0	0	0	271.2	0.0	0.0	0.0	0.4

Table 9-2 Extracted information from area T3

ID Resources	ID Habitat	ID Toxicology	ID Activities	Yield Resources	Yield Habitat	Yield Toxicology	Yield Activities	Area
0	0	0	0	0.0	0.0	0.0	0.0	36.0
0	0	0	5	0.0	0.0	0.0	1457.1	5.8
0	0	0	2	0.0	0.0	0.0	5.0	0.2
0	0	0	1	0.0	0.0	0.0	214.4	0.2
0	0	0	51	0.0	0.0	0.0	235.7	0.2
0	1	0	0	0.0	129.0	0.0	0.0	0.4
0	1	0	2	0.0	0.6	0.0	0.0	0.0
0	1	0	5	0.0	105.1	0.0	74.8	0.3
0	1	0	1	0.0	18.6	0.0	59.5	0.1
0	1	0	51	0.0	16.4	0.0	64.1	0.0
5	0	0	0	17428.6	0.0	0.0	0.0	17.6
5	0	0	2	94.7	0.0	0.0	2.5	0.1
5	0	0	5	5776.2	0.0	0.0	1457.1	5.8
5	1	0	2	1.7	0.6	0.0	0.0	0.0
5	0	0	1	189.1	0.0	0.0	214.4	0.2
5	0	0	51	170.1	0.0	0.0	235.7	0.2
5	1	0	0	364.2	129.0	0.0	0.0	0.4
5	1	0	5	296.7	105.1	0.0	74.8	0.3
5	1	0	1	52.5	18.6	0.0	59.5	0.1
5	1	0	51	46.3	16.4	0.0	64.1	0.0
2	0	0	0	10757.4	0.0	0.0	0.0	7.1
2	0	0	2	23.4	0.0	0.0	0.4	0.0
2	0	0	5	246.8	0.0	0.0	40.7	0.2
52	0	0	0	4163.3	0.0	0.0	0.0	1.7
52	0	0	5	408.1	0.0	0.0	40.7	0.2
1	0	0	0	9120.7	0.0	0.0	0.0	12.2
1	0	0	5	635.8	0.0	0.0	211.3	0.8
51	0	0	0	7121.4	0.0	0.0	0.0	4.1
51	0	0	5	1473.4	0.0	0.0	211.3	0.8
21	0	0	0	1416.0	0.0	0.0	0.0	0.6

Table 9-3 Extracted information from area TSmall

ID Resources	ID Habitat	ID Toxicology	ID Activities	Yield Resources	Yield Habitat	Yield Toxicology	Yield Activities	Area
0	0	0	0	0.0	0.0	0.0	0.0	1.6
0	0	0	5	0.0	0.0	0.0	43.1	0.2
0	0	0	2	0.0	0.0	0.0	16.1	0.6
0	0	0	52	0.0	0.0	0.0	47.7	0.2
0	2	0	0	0.0	252.8	0.0	0.0	0.5
0	2	0	5	0.0	5.2	0.0	2.4	0.0
0	2	0	2	0.0	10.9	0.0	0.5	0.0
0	2	0	52	0.0	5.2	0.0	2.6	0.0
0	1	0	0	0.0	151.7	0.0	0.0	0.4
0	1	0	5	0.0	36.0	0.0	25.6	0.1
0	1	0	2	0.0	45.2	0.0	3.4	0.1
0	1	0	52	0.0	36.0	0.0	28.4	0.1
0	21	0	0	0.0	13.6	0.0	0.0	0.0
0	21	0	5	0.0	3.5	0.0	1.0	0.0
0	21	0	2	0.0	3.5	0.0	0.1	0.0
0	21	0	52	0.0	3.5	0.0	1.1	0.0
5	0	0	0	1060.0	0.0	0.0	0.0	1.1
5	0	0	5	171.0	0.0	0.0	43.1	0.2
5	0	0	2	552.7	0.0	0.0	14.7	0.6
5	0	0	52	171.0	0.0	0.0	47.7	0.2
5	2	0	0	304.6	169.6	0.0	0.0	0.3
5	2	0	5	9.3	5.2	0.0	2.4	0.0
5	2	0	2	19.6	10.9	0.0	0.5	0.0
5	2	0	52	9.3	5.2	0.0	2.6	0.0
5	1	0	0	309.2	109.5	0.0	0.0	0.3
5	1	0	5	101.6	36.0	0.0	25.6	0.1
5	1	0	2	127.7	45.2	0.0	3.4	0.1
5	1	0	52	101.6	36.0	0.0	28.4	0.1
5	21	0	0	11.3	10.3	0.0	0.0	0.0
5	21	0	5	3.8	3.5	0.0	1.0	0.0
5	21	0	2	3.8	3.5	0.0	0.1	0.0
5	21	0	52	3.8	3.5	0.0	1.1	0.0

Table 9-4 Extracted information from area Tg1 with fish farm layer

ID Resources	ID Habitat	ID Toxicology	ID Activities	Yield Resources	Yield Habitat	Yield Toxicology	Yield Activities	Area
0	0	0	0	0.0	0.0	0.0	0.0	4.8
0	0	1	0	0.0	0.0	13.6	0.0	0.0
0	0	0	5	0.0	0.0	0.0	937.6	3.8
0	0	1	5	0.0	0.0	3.6	0.6	0.0
0	0	0	2	0.0	0.0	0.0	55.6	2.1
0	0	1	2	0.0	0.0	13.6	0.2	0.0
0	0	0	52	0.0	0.0	0.0	528.9	1.9
0	0	1	52	0.0	0.0	3.6	0.7	0.0
0	1	0	0	0.0	235.8	0.0	0.0	0.7
0	1	0	5	0.0	168.2	0.0	119.7	0.5
0	1	0	2	0.0	131.8	0.0	9.9	0.4
0	1	0	52	0.0	128.6	0.0	101.2	0.4
5	0	0	0	4743.1	0.0	0.0	0.0	4.8
5	0	1	0	9.0	0.0	13.6	0.0	0.0
5	0	0	5	3716.8	0.0	0.0	937.6	3.8
5	0	1	5	2.4	0.0	3.6	0.6	0.0
5	0	0	2	2083.5	0.0	0.0	55.6	2.1
5	0	1	2	9.0	0.0	13.6	0.2	0.0
5	0	0	52	1896.4	0.0	0.0	528.9	1.9
5	0	1	52	2.4	0.0	3.6	0.7	0.0
5	1	0	0	665.6	235.8	0.0	0.0	0.7
5	1	0	5	474.7	168.2	0.0	119.7	0.5
5	1	0	2	371.9	131.8	0.0	9.9	0.4
5	1	0	52	362.9	128.6	0.0	101.2	0.4
2	0	0	0	108.9	0.0	0.0	0.0	0.1
2	0	0	5	108.9	0.0	0.0	18.0	0.1
52	0	0	0	180.2	0.0	0.0	0.0	0.1
52	0	0	5	180.2	0.0	0.0	18.0	0.1

Table 9-5 Extracted information from area Tg1 without fish farm layer

ID Resources	ID Habitat	ID Toxicology	ID Activities	Yield Resources	Yield Habitat	Yield Toxicology	Yield Activities	Area
0	0	0	0	0.0	0.0	0.0	0.0	4.8
0	0	0	5	0.0	0.0	0.0	937.6	3.8
0	0	1	0	0.0	0.0	13.6	0.0	0.0
0	0	1	5	0.0	0.0	3.6	0.6	0.0
0	1	0	0	0.0	235.8	0.0	0.0	0.7
0	1	0	5	0.0	168.2	0.0	119.7	0.5
5	0	0	0	4743.1	0.0	0.0	0.0	4.8
5	0	0	5	3716.8	0.0	0.0	937.6	3.8
5	0	1	0	9.0	0.0	13.6	0.0	0.0
5	0	1	5	2.4	0.0	3.6	0.6	0.0
5	1	0	0	665.6	235.8	0.0	0.0	0.7
5	1	0	5	474.7	168.2	0.0	119.7	0.5
2	0	0	0	108.9	0.0	0.0	0.0	0.1
2	0	0	5	108.9	0.0	0.0	18.0	0.1
52	0	0	0	180.2	0.0	0.0	0.0	0.1
52	0	0	5	180.2	0.0	0.0	18.0	0.1

Table 9-6 Extracted information from area Tg2 with fish farm layer

ID Resources	ID Habitat	ID Toxicology	ID Activities	Yield Resources	Yield Habitat	Yield Toxicology	Yield Activities	Area
0	0	0	0	0.0	0.0	0.0	0.0	5.4
0	0	0	5	0.0	0.0	0.0	923.3	3.7
0	0	0	2	0.0	0.0	0.0	0.0	0.0
0	0	0	52	0.0	0.0	0.0	0.0	0.0
0	1	0	0	0.0	2.7	0.0	0.0	0.0
0	1	0	5	0.0	2.7	0.0	2.0	0.0
0	1	0	2	0.0	0.0	0.0	0.0	0.0
0	1	0	52	0.0	0.0	0.0	0.0	0.0
5	0	0	0	5309.9	0.0	0.0	0.0	5.4
5	0	0	5	3660.1	0.0	0.0	923.3	3.7
5	0	0	2	0.0	0.0	0.0	0.0	0.0
5	0	0	52	0.0	0.0	0.0	0.0	0.0
5	1	0	0	7.8	2.7	0.0	0.0	0.0
5	1	0	5	7.8	2.7	0.0	2.0	0.0
5	1	0	2	0.0	0.0	0.0	0.0	0.0
5	1	0	52	0.0	0.0	0.0	0.0	0.0
2	0	0	0	3858.3	0.0	0.0	0.0	2.6
2	0	0	5	3379.6	0.0	0.0	557.4	2.2
52	0	0	0	6381.0	0.0	0.0	0.0	2.6
52	0	0	5	5589.3	0.0	0.0	557.4	2.2

Table 9-7 Extracted information from area Tg2 without fish farm layer

ID Resources	ID Habitat	ID Toxicology	ID Activities	Yield Resources	Yield Habitat	Yield Toxicology	Yield Activities	Area
0	0	0	0	0.0	0.0	0.0	0.0	5.4
0	0	0	5	0.0	0.0	0.0	923.3	3.7
0	1	0	0	0.0	2.7	0.0	0.0	0.0
0	1	0	5	0.0	2.7	0.0	2.0	0.0
5	0	0	0	5309.9	0.0	0.0	0.0	5.4
5	0	0	5	3660.1	0.0	0.0	923.3	3.7
5	1	0	0	7.8	2.7	0.0	0.0	0.0
5	1	0	5	7.8	2.7	0.0	2.0	0.0
2	0	0	0	3858.3	0.0	0.0	0.0	2.6
2	0	0	5	3379.6	0.0	0.0	557.4	2.2
52	0	0	0	6381.0	0.0	0.0	0.0	2.6
52	0	0	5	5589.3	0.0	0.0	557.4	2.2

Table 9-8 Extracted information from area Tg3 with fish farm layer

ID Resources	ID Habitat	ID Toxicology	ID Activities	Yield Resources	Yield Habitat	Yield Toxicology	Yield Activities	Area
0	0	0	0	0.0	0.0	0.0	0.0	5.0
0	0	1	0	0.0	0.0	4122.7	0.0	2.7
0	0	0	5	0.0	0.0	0.0	1054.4	4.2
0	0	1	5	0.0	0.0	3724.1	618.8	2.5
0	0	0	2	0.0	0.0	0.0	128.7	4.9
0	0	1	2	0.0	0.0	4079.8	71.7	2.7
0	0	0	52	0.0	0.0	0.0	1135.7	4.1
0	0	1	52	0.0	0.0	3681.1	676.3	2.5
0	1	0	0	0.0	140.5	0.0	0.0	0.4
0	1	0	5	0.0	92.1	0.0	65.6	0.3
0	1	0	2	0.0	139.5	0.0	10.5	0.4
0	1	0	52	0.0	91.2	0.0	71.8	0.3
5	0	0	0	4935.8	0.0	0.0	0.0	5.0
5	0	1	0	2715.5	0.0	4122.7	0.0	2.7
5	0	0	5	4179.9	0.0	0.0	1054.4	4.2
5	0	1	5	2452.9	0.0	3724.1	618.8	2.5
5	0	0	2	4827.6	0.0	0.0	128.7	4.9
5	0	1	2	2687.2	0.0	4079.8	71.7	2.7
5	0	0	52	4071.7	0.0	0.0	1135.7	4.1
5	0	1	52	2424.6	0.0	3681.1	676.3	2.5
5	1	0	0	396.5	140.5	0.0	0.0	0.4
5	1	0	5	260.0	92.1	0.0	65.6	0.3
5	1	0	2	393.9	139.5	0.0	10.5	0.4
5	1	0	52	257.4	91.2	0.0	71.8	0.3
2	0	0	0	32.3	0.0	0.0	0.0	0.0
2	0	1	0	32.3	0.0	32.1	0.0	0.0
2	0	0	5	32.3	0.0	0.0	5.3	0.0
2	0	1	5	32.3	0.0	32.1	5.3	0.0
2	0	0	2	32.3	0.0	0.0	0.6	0.0
2	0	1	2	32.3	0.0	32.1	0.6	0.0
2	0	0	52	32.3	0.0	0.0	5.9	0.0
2	0	1	52	32.3	0.0	32.1	5.9	0.0
52	0	0	0	53.5	0.0	0.0	0.0	0.0
52	0	1	0	53.5	0.0	32.1	0.0	0.0
52	0	0	5	53.5	0.0	0.0	5.3	0.0
52	0	1	5	53.5	0.0	32.1	5.3	0.0
52	0	0	2	53.5	0.0	0.0	0.6	0.0
52	0	1	2	53.5	0.0	32.1	0.6	0.0
52	0	0	52	53.5	0.0	0.0	5.9	0.0
52	0	1	52	53.5	0.0	32.1	5.9	0.0

Table 9-9 Extracted information from area Tg3 without fish farm layer

ID Resources	ID Habitat	ID Toxicology	ID Activities	Yield Resources	Yield Habitat	Yield Toxicology	Yield Activities	Area
0	0	0	0	0.0	0.0	0.0	0.0	5.0
0	0	0	5	0.0	0.0	0.0	1054.3	4.2
0	0	1	0	0.0	0.0	4122.6	0.0	2.7
0	0	1	5	0.0	0.0	3724.1	618.8	2.5
0	1	0	0	0.0	140.5	0.0	0.0	0.4
0	1	0	5	0.0	92.1	0.0	65.6	0.3
5	0	0	0	4935.8	0.0	0.0	0.0	5.0
5	0	0	5	4179.8	0.0	0.0	1054.4	4.2
5	0	1	0	2715.4	0.0	4122.6	0.0	2.7
5	0	1	5	2452.9	0.0	3724.1	618.8	2.5
5	1	0	0	396.5	140.5	0.0	0.0	0.4
5	1	0	5	260.0	92.1	0.0	65.6	0.3
2	0	0	0	32.3	0.0	0.0	0.0	0.0
2	0	0	5	32.3	0.0	0.0	5.3	0.0
2	0	1	0	32.3	0.0	32.1	0.0	0.0
2	0	1	5	32.3	0.0	32.1	5.3	0.0
52	0	0	0	53.5	0.0	0.0	0.0	0.0
52	0	0	5	53.5	0.0	0.0	5.3	0.0
52	0	1	0	53.5	0.0	32.1	0.0	0.0
52	0	1	5	53.5	0.0	32.1	5.3	0.0

Table 9-10 Extracted information from area Tg4 with fish farm layer

ID Resources	ID Habitat	ID Toxicology	ID Activities	Yield Resources	Yield Habitat	Yield Toxicology	Yield Activities	Area
0	0	0	0	0.0	0.0	0.0	0.0	5.2
0	0	0	0	0.0	0.0	0.0	0.0	0.0
0	0	1	0	0.0	0.0	1193.8	0.0	0.8
0	0	0	5	0.0	0.0	0.0	512.3	2.1
0	0	1	5	0.0	0.0	1159.1	192.6	0.8
0	0	0	5	0.0	0.0	0.0	0.2	0.0
0	0	0	2	0.0	0.0	0.0	32.3	1.2
0	0	1	2	0.0	0.0	830.5	14.6	0.6
0	0	0	2	0.0	0.0	0.0	0.0	0.0
0	0	0	52	0.0	0.0	0.0	233.1	0.8
0	0	0	52	0.0	0.0	0.0	0.3	0.0
0	0	1	52	0.0	0.0	802.3	147.4	0.5
0	0	0	1	0.0	0.0	0.0	932.5	0.8
0	0	1	1	0.0	0.0	663.0	495.0	0.4
0	0	0	51	0.0	0.0	0.0	1022.1	0.7
0	0	1	51	0.0	0.0	628.3	573.5	0.4
0	0	0	21	0.0	0.0	0.0	309.5	0.3
0	0	1	21	0.0	0.0	353.6	270.2	0.2
0	0	0	521	0.0	0.0	0.0	329.1	0.2
0	0	1	521	0.0	0.0	325.4	302.7	0.2
0	1	0	0	0.0	80.5	0.0	0.0	0.2
0	1	0	0	0.0	0.3	0.0	0.0	0.0
0	1	0	5	0.0	46.7	0.0	33.2	0.1
0	1	0	5	0.0	0.3	0.0	0.2	0.0
0	1	0	2	0.0	80.1	0.0	6.0	0.2
0	1	0	2	0.0	0.3	0.0	0.0	0.0
0	1	0	52	0.0	46.7	0.0	36.8	0.1
0	1	0	52	0.0	0.3	0.0	0.3	0.0
5	0	0	0	5141.5	0.0	0.0	0.0	5.2
5	0	1	0	786.3	0.0	1193.8	0.0	0.8
5	0	0	0	0.9	0.0	0.0	0.0	0.0
5	0	0	5	2031.0	0.0	0.0	512.3	2.1
5	0	0	5	0.9	0.0	0.0	0.2	0.0
5	0	1	5	763.5	0.0	1159.2	192.6	0.8
5	0	0	2	1210.3	0.0	0.0	32.3	1.2
5	0	0	2	0.9	0.0	0.0	0.0	0.0
5	0	1	2	547.0	0.0	830.5	14.6	0.6
5	0	0	52	835.6	0.0	0.0	233.1	0.8
5	0	1	52	528.4	0.0	802.3	147.4	0.5
5	0	0	52	0.9	0.0	0.0	0.3	0.0
5	1	0	0	227.3	80.5	0.0	0.0	0.2
5	0	0	1	822.6	0.0	0.0	932.5	0.8

5	1	0	0	0.9	0.3	0.0	0.0	0.0
5	0	1	1	436.7	0.0	663.0	495.0	0.4
5	0	0	51	737.5	0.0	0.0	1022.1	0.7
5	1	0	5	131.8	46.7	0.0	33.2	0.1
5	1	0	5	0.9	0.3	0.0	0.2	0.0
5	0	1	51	413.8	0.0	628.3	573.5	0.4
5	0	0	21	266.7	0.0	0.0	309.5	0.3
5	1	0	2	226.1	80.1	0.0	6.0	0.2
5	1	0	2	0.9	0.3	0.0	0.0	0.0
5	0	1	21	232.9	0.0	353.6	270.2	0.2
5	0	0	521	233.0	0.0	0.0	329.1	0.2
5	1	0	52	131.8	46.7	0.0	36.8	0.1
5	1	0	52	0.9	0.3	0.0	0.3	0.0
5	0	1	521	214.3	0.0	325.4	302.7	0.2
2	0	0	0	6637.3	0.0	0.0	0.0	4.4
2	0	1	0	865.7	0.0	859.3	0.0	0.6
2	0	0	5	2414.2	0.0	0.0	398.2	1.6
2	0	1	5	830.8	0.0	824.7	137.0	0.5
2	0	0	2	915.8	0.0	0.0	16.0	0.6
2	0	1	2	536.1	0.0	532.1	9.3	0.4
2	0	0	52	622.2	0.0	0.0	113.5	0.4
2	0	1	52	507.6	0.0	503.9	92.6	0.3
2	0	0	1	1257.9	0.0	0.0	932.3	0.8
2	0	1	1	667.6	0.0	662.7	494.8	0.4
2	0	0	51	1127.8	0.0	0.0	1021.9	0.7
2	0	1	51	632.7	0.0	628.0	573.3	0.4
2	0	0	21	408.0	0.0	0.0	309.5	0.3
2	0	1	21	356.2	0.0	353.6	270.2	0.2
2	0	0	521	356.4	0.0	0.0	329.1	0.2
2	0	1	521	327.8	0.0	325.4	302.7	0.2
52	0	0	0	10976.8	0.0	0.0	0.0	4.4
52	0	1	0	1431.7	0.0	859.3	0.0	0.6
52	0	0	5	3992.6	0.0	0.0	398.2	1.6
52	0	1	5	1374.0	0.0	824.7	137.0	0.5
52	0	0	2	1514.6	0.0	0.0	16.0	0.6
52	0	1	2	886.6	0.0	532.1	9.3	0.4
52	0	0	52	1029.0	0.0	0.0	113.5	0.4
52	0	1	52	839.5	0.0	503.9	92.6	0.3
52	0	0	1	2080.3	0.0	0.0	932.3	0.8
52	0	1	1	1104.1	0.0	662.7	494.8	0.4
52	0	0	51	1865.2	0.0	0.0	1021.9	0.7
52	0	1	51	1046.4	0.0	628.0	573.3	0.4
52	0	0	21	674.7	0.0	0.0	309.5	0.3
52	0	1	21	589.1	0.0	353.6	270.2	0.2
52	0	0	521	589.3	0.0	0.0	329.1	0.2
52	0	1	521	542.1	0.0	325.4	302.7	0.2

Table 9-11 Extracted information from area Tg4 without fish farm layer

ID Resources	ID Habitat	ID Toxicology	ID Activities	Yield Resources	Yield Habitat	Yield Toxicology	Yield Activities	Area
0	0	0	0	0.0	0.0	0.0	0.0	5.2
0	0	0	0	0.0	0.0	0.0	0.0	0.0
0	0	0	5	0.0	0.0	0.0	512.3	2.1
0	0	0	5	0.0	0.0	0.0	0.2	0.0
0	0	0	1	0.0	0.0	0.0	932.5	0.8
0	0	0	51	0.0	0.0	0.0	1022.1	0.7
0	0	1	0	0.0	0.0	1193.8	0.0	0.8
0	0	1	5	0.0	0.0	1159.1	192.6	0.8
0	0	1	1	0.0	0.0	663.0	495.0	0.4
0	0	1	51	0.0	0.0	628.3	573.5	0.4
0	1	0	0	0.0	80.5	0.0	0.0	0.2
0	1	0	0	0.0	0.3	0.0	0.0	0.0
0	1	0	5	0.0	46.7	0.0	33.2	0.1
0	1	0	5	0.0	0.3	0.0	0.2	0.0
5	0	0	0	5141.5	0.0	0.0	0.0	5.2
5	0	0	1	822.6	0.0	0.0	932.5	0.8
5	0	0	0	0.9	0.0	0.0	0.0	0.0
5	0	0	5	2031.0	0.0	0.0	512.3	2.1
5	0	0	51	737.5	0.0	0.0	1022.1	0.7
5	0	0	5	0.9	0.0	0.0	0.2	0.0
5	1	0	0	0.9	0.3	0.0	0.0	0.0
5	0	1	0	786.3	0.0	1193.8	0.0	0.8
5	1	0	5	0.9	0.3	0.0	0.2	0.0
5	0	1	5	763.5	0.0	1159.1	192.6	0.8
5	1	0	0	227.3	80.5	0.0	0.0	0.2
5	0	1	1	436.7	0.0	663.0	495.0	0.4
5	0	1	51	413.8	0.0	628.3	573.5	0.4
5	1	0	5	131.8	46.7	0.0	33.2	0.1
2	0	0	0	6637.3	0.0	0.0	0.0	4.4
2	0	0	5	2414.2	0.0	0.0	398.2	1.6
2	0	0	1	1257.9	0.0	0.0	932.3	0.8
2	0	0	51	1127.8	0.0	0.0	1021.9	0.7
2	0	1	0	865.7	0.0	859.3	0.0	0.6
2	0	1	5	830.8	0.0	824.7	137.0	0.5
2	0	1	1	667.6	0.0	662.7	494.8	0.4
2	0	1	51	632.7	0.0	628.0	573.3	0.4
52	0	0	0	10976.8	0.0	0.0	0.0	4.4
52	0	0	1	2080.3	0.0	0.0	932.3	0.8
52	0	0	5	3992.6	0.0	0.0	398.2	1.6
52	0	0	51	1865.2	0.0	0.0	1021.9	0.7
52	0	1	0	1431.7	0.0	859.3	0.0	0.6
52	0	1	5	1374.0	0.0	824.7	137.0	0.5

52	0	1	1	1104.1	0.0	662.7	494.8	0.4
52	0	1	51	1046.4	0.0	628.0	573.3	0.4

10 Program codes

```
'****************************************************************************
'
' frmResources.vb corresponds to the click of selecting subcomponents of Resources
'
'****************************************************************************
Public Class frmResources

    Inherits System.Windows.Forms.Form
    Public Shared yearUrchin, yearHerringDay, yearHerringNight as String

#Region " Windows Form Designer generated code "333
......
#End Region

    Private Sub btnContinue_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles btnContinue.Click
        Dim colorValue As Long
        Dim stmt, colorStr, chrYear

        Dim JudgeTable As Integer 'To judge whether a table is open or not
        Dim AfrmMain As New frmMain()
        chrYear = LTrim(AfrmMain.strYear)

        Select Case chrYear
            Case "1998"
                yearHerringDay = "HerringDay"
                yearHerringNight = "HerringNight"
                yearUrchin = "U1998Buffer20"
            Case "1999"
                yearHerringDay = "HerringDay"
                yearHerringNight = "HerringNight"
                yearUrchin = "U1999Buffer20"
            Case "2000"
                yearHerringDay = "HerringDay"
                yearHerringNight = "HerringNight"
                yearUrchin = "U2000Buffer20"
            Case "2001"
                yearHerringDay = "HerringDay"
                yearHerringNight = "HerringNight"
                yearUrchin = "U2001Buffer20"
            Case "2002"
                yearHerringDay = "HerringDay"
                yearHerringNight = "HerringNight"
                yearUrchin = "U2002Buffer20"
            Case Else
                'MsgBox "Something wrong for year data selection!"
                MsgBox("FrmMain.cmbYear.Text = " + chrYear + " Wrong?")
                Exit Sub
        End Select

        'For HerryingDay
        ShowLayerOrNot(yearHerringDay, chkHerringDay.Checked)

        'For HerryingNight
        ShowLayerOrNot(yearHerringNight, ChkHerringNight.Checked)

        'For Urchins
        'MsgBox("yearUrchin " & yearUrchin)
        ShowLayerOrNot(yearUrchin, chkUrchins.Checked)

        'Finally hide the form
        Me.Hide()
    End Sub

    Private Sub frmResources_Load(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles MyBase.Load
        'If one layer is added, then when you open the select window, the coresopnding chkbox should be checked.
        If (LayerAddedOrNot(yearHerringDay) > 0) Then Me.chkHerringDay.Checked = True
        If (LayerAddedOrNot(yearHerringNight) > 0) Then Me.ChkHerringNight.Checked = True
        If (LayerAddedOrNot(yearUrchin) > 0) Then Me.chkUrchins.Checked = True
    End Sub
```

```
Public Function ShowLayer(ByVal JudgeTable As Integer, ByVal LayerName As String, ByVal Operation As String, Optional ByVal pathName
As String = "") As String
    Dim ndx, count As Integer
    Dim NumRepeat As Integer = 0

    'Calculate the total layers again. Note, the value is possible change
    count = Val(frmMain.mi.Eval("MapperInfo(" & frmMain.mapid & ",9)"))

    'Accumulate the repeated number if one layer is showed more than one times
    For ndx = 1 To count
        If (frmMain.mi.Eval("LayerInfo(" & frmMain.mapid & "," & ndx & ",1)") = LayerName) Then
            NumRepeat = NumRepeat + 1
        End If
    Next

    If (Operation = "Show") Then 'Show a table
        'Open and show a table if it is checked and it doesn't open
        If (frmMain.OpenResources(JudgeTable) = False) Then
            frmMain.mi.Do("Open Table """ + pathName + LayerName + ".TAB"" Interactive")
            'If the table of Herring is open, the corresponding boolean OpenResources(0) is set as true
            frmMain.OpenResources(JudgeTable) = True
            'Show the open table in the picturebox
            frmMain.mi.Do("Add Map Auto Layer " + LayerName)
        Else 'Show the table which is opened
            If (count > 0) Then
                If (NumRepeat = 0) Then
                    frmMain.mi.Do("Add Map Auto Layer " + LayerName)
                ElseIf (NumRepeat > 1) Then 'Remove repeated layers
                    For ndx = 1 To (NumRepeat - 1)
                        frmMain.mi.Do("Remove Map Layer """ + LayerName + """")
                    Next
                End If
            Else 'The background GMIsland2 is disappear?

                MsgBox("Is this the first layer?")
                Exit Function
            End If
        End If
    End If

    If (Operation = "Hide") Then 'Hide a table
        If (NumRepeat > 0) Then 'Remove repeated layers
            For ndx = 1 To NumRepeat
                MessageBox.Show("Now you are in the Hide part! and want to: " & "Remove Map Layer """ + LayerName + """")
                frmMain.mi.Do("Remove Map Layer """ + LayerName + """")

            Next
        End If
    End If
End Function

Public Function ShowLayerOrNot(ByVal strName As Object, ByVal chkState As Integer) As String
    'This function is used to simplify the repeated process of show different layer.
    'strName is the layer name or the table name, pathName is the table's location, chkState represents the box is checked or not.
    Dim num As Integer
    'MsgBox("Homedirectory$() " & frmMain.mi.Eval("Homedirectory$()"))
    'MsgBox("ApplicationDirectory$() " & frmMain.mi.Eval("ApplicationDirectory$()"))
    'MsgBox("ProgramDirectory$() " & frmMain.mi.Eval("ProgramDirectory$()"))
    'MsgBox("chkState " & chkState)
    If (chkState) Then
        If (TableOpenedOrNot(strName) = 0) Then 'The table named strName is not opened yet
            frmMain.mi.Do("Open Table """ + frmMain.pathName + strName + ".TAB"" Interactive")
            'If you omit the pathName, then the program will ask you to point it by pop up the openwindow.
        End If
        If (LayerAddedOrNot(strName) = 0) Then 'The Layer named strName is not added yet
            frmMain.mi.Do("Add Map Auto Layer " + strName)
        End If
    Else
        If (LayerAddedOrNot(strName) > 0) Then 'The Layer named strName is added several times = LayerAddedOrNot(strName)
```

```
      frmMain.mi.Do("Add Map Auto Layer " + strName)
      For num = 1 To LayerAddedOrNot(strName)
        frmMain.mi.Do("Remove Map Layer """ + strName + """")
      Next
    End If
  End If
End Function

Public Function LayerAddedOrNot(ByVal LayerName As Object) As Integer
  'If LayerName is added 1 time, then return 1; N times, return N.
  Dim ndx, count As Integer
  Dim NumAdded As Integer = 0

  'Calculate the total opened layers
  count = Val(frmMain.mi.Eval("MapperInfo(" & frmMain.mapid & ",9)"))

  'Check whether the LayerName is displayed
  For ndx = 1 To count
    If (frmMain.mi.Eval("LayerInfo(" & frmMain.mapid & "," & ndx & ",1)") = LayerName) Then
      NumAdded = NumAdded + 1
    End If
  Next
  Return NumAdded
End Function

Public Function TableOpenedOrNot(ByVal TableName As Object) As Integer
  'If TableName is opened, return 1, else 0
  Dim i, table_count As Integer

  'Determine the number of opened tables
  table_count = frmMain.mi.Eval("NumTables()")

  'Check whether the TableName is opened
  For i = 1 To table_count
    'check the name of table # i
    If TableName = frmMain.mi.Eval("TableInfo(" & i & ", 1)") Then
      TableOpenedOrNot = 1
      Exit Function
    End If
  Next
  TableOpenedOrNot = 0
End Function

End Class
```

```
'******************************************************************************
'
' frmHabitat.vb corresponds to the click of selecting subcomponents of Habitat
'
'******************************************************************************

Public Class frmHabitat
   Inherits System.Windows.Forms.Form
Public Shared strRockweed, strSaltmarsh As String

#Region " Windows Form Designer generated code "
......
#End Region

   Private Sub btnContinue_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles btnContinue.Click

      'For Rockweed
      strRockweed = "RockweedBuffer01CutLand"
      ShowLayerOrNot(strRockweed, ChkRockweed.Checked)

      'For Saltmarsh
      strSaltmarsh = "Saltmarsh"
      ShowLayerOrNot(strSaltmarsh, ChkSaltMarshes.Checked)

      If ChkCurrentFlow.Checked Then
      End If

      If ChkBottomComposition.Checked Then
      End If

      'Finally hide this form
      Me.Hide()

   End Sub

   Private Sub frmHabitat_Load(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles MyBase.Load
      If (LayerAddedOrNot(strRockweed) > 0) Then Me.ChkRockweed.Checked = True
      If (LayerAddedOrNot(strSaltmarsh) > 0) Then Me.ChkSaltMarshes.Checked = True
   End Sub


   Public Function ShowLayerOrNot(ByVal strName As Object, ByVal chkState As Integer) As String
      'This function is used to simplify the repeated process of show different layer.
      'strName is the layer name or the table name, pathName is the table's location, chkState represents the box is checked or not.
      Dim num As Integer
      If (chkState) Then
         If (TableOpenedOrNot(strName) = 0) Then 'The table named strName is not opened yet
            frmMain.mi.Do("Open Table """ + frmMain.pathName + strName + ".TAB"" Interactive")
         End If
         If (LayerAddedOrNot(strName) = 0) Then 'The Layer named strName is not added yet
            frmMain.mi.Do("Add Map Auto Layer " + strName)
         End If
      Else
         If (LayerAddedOrNot(strName) > 0) Then 'The Layer named strName is added several times = LayerAddedOrNot(strName)
            frmMain.mi.Do("Add Map Auto Layer " + strName)
            For num = 1 To LayerAddedOrNot(strName)
               frmMain.mi.Do("Remove Map Layer """ + strName + """")
            Next
         End If
      End If
   End Function

   Public Function LayerAddedOrNot(ByVal LayerName As Object) As Integer
      'If LayerName is added 1 time, then return 1; N times, return N.
      Dim ndx, count As Integer
      Dim NumAdded As Integer = 0

      'Calculate the total opened layers
      count = Val(frmMain.mi.Eval("MapperInfo(" & frmMain.mapid & ",9)"))
```

```
    'Check whether the LayerName is displayed
    For ndx = 1 To count
      If (frmMain.mi.Eval("LayerInfo(" & frmMain.mapid & "," & ndx & ",1)") = LayerName) Then
        NumAdded = NumAdded + 1
      End If
    Next
    Return NumAdded
  End Function

  Public Function TableOpenedOrNot(ByVal TableName As Object) As Integer
    'If TableName is opened, return 1, else 0
    Dim i, table_count As Integer

    'Determine the number of opened tables
    table_count = frmMain.mi.Eval("NumTables()")

    'Check whether the TableName is opened
    For i = 1 To table_count
      'check the name of table # i
      If TableName = frmMain.mi.Eval("TableInfo(" & i & ", 1)") Then
        TableOpenedOrNot = 1
        Exit Function
      End If
    Next
    TableOpenedOrNot = 0
  End Function

End Class
```

```
'*****************************************************************************
'
' frmToxicology.vb corresponds to the click of selecting subcomponents of Toxicology
'
'*****************************************************************************

Public Class frmToxicology
   Inherits System.Windows.Forms.Form
   Public Shared strChemicalA As String
#Region " Windows Form Designer generated code "
......
#End Region

   Private Sub btnContinue_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles btnContinue.Click
      'For ChemicalA
      strChemicalA = "ChemicalA"
      ShowLayerOrNot(strChemicalA, ChkChemicalA.Checked)

      Me.Hide()
   End Sub

   Private Sub frmToxicology_Load(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles MyBase.Load
      If (LayerAddedOrNot(strChemicalA) > 0) Then Me.ChkChemicalA.Checked = True
   End Sub

   Public Function ShowLayerOrNot(ByVal strName As Object, ByVal chkState As Integer) As String
      'This function is used to simplify the repeated process of show different layer.
      'strName is the layer name or the table name, pathName is the table's location, chkState represents the box is checked or not.
      Dim num As Integer
      'MsgBox("Homedirectory$() " & frmMain.mi.Eval("Homedirectory$()"))
      'MsgBox("ApplicationDirectory$() " & frmMain.mi.Eval("ApplicationDirectory$()"))
      'MsgBox("ProgramDirectory$() " & frmMain.mi.Eval("ProgramDirectory$()"))
      'MsgBox("chkState " & chkState)
      If (chkState) Then
         If (TableOpenedOrNot(strName) = 0) Then 'The table named strName is not opened yet
            frmMain.mi.Do("Open Table """ + frmMain.pathName + strName + ".TAB"" Interactive")
         End If
         If (LayerAddedOrNot(strName) = 0) Then 'The Layer named strName is not added yet
            frmMain.mi.Do("Add Map Auto Layer " + strName)
         End If
      Else
         If (LayerAddedOrNot(strName) > 0) Then 'The Layer named strName is added several times = LayerAddedOrNot(strName)
            frmMain.mi.Do("Add Map Auto Layer " + strName)
            For num = 1 To LayerAddedOrNot(strName)
               frmMain.mi.Do("Remove Map Layer """ + strName + """")
            Next
         End If
      End If
   End Function

   Public Function LayerAddedOrNot(ByVal LayerName As Object) As Integer
      'If LayerName is added 1 time, then return 1; N times, return N.
      Dim ndx, count As Integer
      Dim NumAdded As Integer = 0

      'Calculate the total opened layers
      count = Val(frmMain.mi.Eval("MapperInfo(" & frmMain.mapid & ",9)"))

      'Check whether the LayerName is displayed
      For ndx = 1 To count
         If (frmMain.mi.Eval("LayerInfo(" & frmMain.mapid & "," & ndx & ",1)") = LayerName) Then
            NumAdded = NumAdded + 1
         End If
      Next
      Return NumAdded
   End Function

   Public Function TableOpenedOrNot(ByVal TableName As Object) As Integer
      'If TableName is opened, return 1, else 0
      Dim i, table_count As Integer
```

```
    'Determine the number of opened tables
    table_count = frmMain.mi.Eval("NumTables()")

    'Check whether the TableName is opened
    For i = 1 To table_count
      'check the name of table # i
      If TableName = frmMain.mi.Eval("TableInfo(" & i & ", 1)") Then
        TableOpenedOrNot = 1
        Exit Function
      End If
    Next
    TableOpenedOrNot = 0
  End Function

End Class
```

```
'******************************************************************************
'
' frmActivities.vb is used to deal with the click of Activities Buttorn
'
'******************************************************************************

Public Class frmActivities
    Inherits System.Windows.Forms.Form
    Public Shared yearHerringWeirs, yearFishFarms, yearLobsterTraps, yearScallopDrags, yearUrchinDrags As String

#Region " Windows Form Designer generated code "
......
#End Region

    Private Sub btnContinue_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles btnContinue.Click
        Dim OverLapName, SQLSentence, chrYear As String
        Dim AfrmMain As New frmMain
        chrYear = LTrim(AfrmMain.strYear)
        '-------------------------------------------
        Select Case LTrim(chrYear)
            Case "1998"
                yearHerringWeirs = "Weir1998Buffer05"
                yearFishFarms = "FF1998Buffer10"
                yearUrchinDrags = "U1998Buffer10Cutland"
            Case "1999"
                yearHerringWeirs = "Weir1999Buffer05"
                yearFishFarms = "FF1999Buffer10"
                yearUrchinDrags = "U1999Buffer10Cutland"
            Case "2000"
                yearHerringWeirs = "Weir2000Buffer05"
                yearFishFarms = "FF2000Buffer10"
                yearUrchinDrags = "U2000Buffer10Cutland"
            Case "2001"
                yearHerringWeirs = "Weir2001Buffer05"
                yearFishFarms = "FF2001Buffer10"
                yearUrchinDrags = "U2001Buffer10Cutland"
            Case "2002"
                yearHerringWeirs = "Weir2002Buffer05"
                yearFishFarms = "FF2002Buffer10"
                yearUrchinDrags = "U2002Buffer10Cutland"
            Case Else
                MsgBox("FrmMain.cmbYear.Text = " + chrYear + " Wrong?")
                Exit Sub
        End Select
        '-------------------------------------------

        'For Herring Weirs
        ShowLayerOrNot(yearHerringWeirs, chkHerringWeirs.Checked)

        'For Fish Farms
        ShowLayerOrNot(yearFishFarms, chkFishFarms.Checked)


        If chkLobsterTraps.Checked Then
        End If

        If chkScallopDrags.Checked Then
        End If

        'For Urchin Drags
        ShowLayerOrNot(yearUrchinDrags, chkUrchinDrags.Checked)

        Me.Hide()
    End Sub

    Public Function ShowLayerOrNot(ByVal strName As Object, ByVal chkState As Integer) As String
        'This function is used to simplify the repeated process of showing different layer.
        'strName is the layer name or the table name, pathName is the table's location, chkState represents the box is checked or not.
        Dim num As Integer
        If (chkState) Then
```

```
      If (TableOpenedOrNot(strName) = 0) Then 'The table named strName is not opened yet
        frmMain.mi.Do("Open Table """ + frmMain.pathName + strName + ".TAB"" Interactive")
        'If you omit the pathName, then the program will ask you to point it by pop up the openwindow.
      End If
      If (LayerAddedOrNot(strName) = 0) Then 'The Layer named strName is not added yet
        frmMain.mi.Do("Add Map Auto Layer " + strName)
      End If
    Else
      If (LayerAddedOrNot(strName) > 0) Then 'The Layer named strName is added several times = LayerAddedOrNot(strName)
        frmMain.mi.Do("Add Map Auto Layer " + strName)
        For num = 1 To LayerAddedOrNot(strName)
          frmMain.mi.Do("Remove Map Layer """ + strName + """")
        Next
      End If
    End If
  End Function

  Public Function LayerAddedOrNot(ByVal LayerName As Object) As Integer
    'If LayerName is added 1 time, then return 1; N times, return N.
    Dim ndx, count As Integer
    Dim NumAdded As Integer = 0

    'Calculate the total opened layers
    count = Val(frmMain.mi.Eval("MapperInfo(" & frmMain.mapid & ",9)"))

    'Check whether the LayerName is displayed
    For ndx = 1 To count
      If (frmMain.mi.Eval("LayerInfo(" & frmMain.mapid & "," & ndx & ",1)") = LayerName) Then
        NumAdded = NumAdded + 1
      End If
    Next
    Return NumAdded
  End Function

  Public Function TableOpenedOrNot(ByVal TableName As Object) As Integer
    'If TableName is opened, return 1, else 0
    Dim i, table_count As Integer

    'Determine the number of opened tables
    table_count = frmMain.mi.Eval("NumTables()")

    'Check whether the TableName is opened
    For i = 1 To table_count
      'check the name of table # i
      If TableName = frmMain.mi.Eval("TableInfo(" & i & ", 1)") Then
        TableOpenedOrNot = 1
        Exit Function
      End If
    Next
    TableOpenedOrNot = 0
  End Function

  Private Sub frmActivities_Load(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles MyBase.Load
    If (LayerAddedOrNot(yearHerringWeirs) > 0) Then Me.chkHerringWeirs.Checked = True
    If (LayerAddedOrNot(yearFishFarms) > 0) Then Me.chkFishFarms.Checked = True
    If (LayerAddedOrNot(yearUrchinDrags) > 0) Then Me.chkUrchinDrags.Checked = True

  End Sub
End Class
```

```
'******************************************************************************
'
'frmSelectTool.vb corresponds to the click of selecting different tools
'
'******************************************************************************

Public Class frmSelectTool
    Inherits System.Windows.Forms.Form

#Region " Windows Form Designer generated code "
......
#End Region

    Private Sub btnPolygon_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles btnPolygon.Click
        frmMain.mi.RunMenuCommand(1714) 'Polygon
        Me.Hide()
    End Sub

    Private Sub btnEllipse_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles btnEllipse.Click
        frmMain.mi.RunMenuCommand(1715) 'Ellipse
        Me.Hide()
    End Sub

    Private Sub btnRectangle_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles btnRectangle.Click
        frmMain.mi.RunMenuCommand(1717) 'Rectangle
        Me.Hide()
    End Sub

    Private Sub BtnRoundedRectangle_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles BtnRoundedRectangle.Click
        frmMain.mi.RunMenuCommand(1718) 'Rounded Rectangle
        Me.Hide()
    End Sub

    Private Sub Button1_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles Button1.Click
        Dim strStatement As String
        strStatement = frmMain.strCreatedTableName
        If strStatement = "" Then
            MsgBox("You have not pointed the created layer!")
            Exit Sub
        End If
        frmMain.mi.do("Insert Into " & frmMain.strTableName & " ( COL1, COL2, COL3, COL4, COL5, COL6) Select COL1, COL2, COL3, COL4,
COL5, COL6 From " & frmMain.strCreatedTableName)
        frmMain.mi.do("Close Table " & strStatement)
        Me.Hide()
    End Sub

    Public Sub frmSelectTool_Load(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles MyBase.Load
        Button1.Text = "By " & frmMain.strCreatedTableName
    End Sub
End Class
```

```
'*****************************************************************************
'
' frmBrowseTable.vb is used to browse those opened tables
'
'*****************************************************************************

Public Class frmBrowseTable
Inherits System.Windows.Forms.Form

#Region " Windows Form Designer generated code "
......
#End Region

    Private Sub frmBrowseTable_Load(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles MyBase.Load
        Dim i, table_count As Integer
        Dim tablenames() As String

        'Determine the number of open tables

        table_count = frmMain.mi.Eval("NumTables()")

        ' Set the selection mode to multiple and extended.
        ListBox.SelectionMode = SelectionMode.MultiExtended

        'Resize the array so that it can hold all of the table names.
        ReDim tablenames(table_count)
        'Loop through the tables
        For i = 1 To table_count
            'read the name of table # i
            tablenames(i) = frmMain.mi.Eval("TableInfo(" & i & ", 1)")
            'put table names as items into the ListBox
            ListBox.Items.Add(tablenames(i))
        Next

    End Sub

    Private Sub btnBrowse_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles btnBrowse.Click
        Dim i, ItemCount As Integer
        ItemCount = ListBox.SelectedItems.Count()
        For i = 0 To ItemCount - 1
            frmMain.mi.Do("set next document parent " & frmMain.PictureBox1Handle & "style 3")
            frmMain.mi.Do("Browse * from " & ListBox.SelectedItems(i).ToString())

            'frmMain.mi.do("Browse * from " & ListBox.SelectedItem)
            frmMain.mi.Do("Browse * from " & ListBox.SelectedItems(i).ToString())
        Next
        Me.Hide()
    End Sub

    Private Sub btnCancel_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles btnCancel.Click
        Me.Hide()
    End Sub

    Private Sub BtnClose_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles BtnClose.Click
        Dim i, ItemCount As Integer
        ItemCount = ListBox.SelectedItems.Count()
        'MsgBox("There are " & ItemCount.ToString & " selected tables!")
        For i = 0 To ItemCount - 1
            frmMain.mi.do("Close Table " & ListBox.SelectedItems(i).ToString() & " Interactive")
        Next
        Me.Hide()
    End Sub

    Private Sub btnSaveClose_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles btnSaveClose.Click
        Dim i, ItemCount As Integer
        Dim strFullTableName As String
        ItemCount = ListBox.SelectedItems.Count()
        'MsgBox("There are " & ItemCount.ToString & " selected tables!")
        For i = 0 To ItemCount - 1
            strFullTableName = frmMain.mi.Eval("FileSaveAsDlg("""", " & ListBox.SelectedItems(i).ToString() & ", ""Tab"", ""Save Table as"")")
```

```
      frmMain.mi.do("Commit Table " & ListBox.SelectedItems(i).ToString() & " As """ & strFullTableName & """")
    Next
    Me.Hide()
  End Sub
End Class
```

```
'*******************************************************************************
'
' frmDoECAnalysis.vb corresponds to the button click of selecting different Expert Choice Model
'
'*******************************************************************************

Public Class frmDoECAnalysis
    Inherits System.Windows.Forms.Form

#Region " Windows Form Designer generated code "
......
#End Region

    Private Sub BtnScientist_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles BtnScientist.Click
        'Hide me firstly
        Me.Hide()

        Dim SimpleName, FullName As String
        SimpleName = "AquacultureScientist.ahp"
        'FullName = frmMain.pathName + "..\AHP-ExpertChoice\" + SimpleName
        FullName = "..\AHP-ExpertChoice\" + SimpleName
        'MsgBox(FullName)

        'Do some judge
        Dim msg As String
        Dim title As String
        Dim style As MsgBoxStyle
        Dim response As MsgBoxResult

        msg = "You will open " + SimpleName + "! Be sure it is existent!"
        style = MsgBoxStyle.Question Or MsgBoxStyle.Critical Or MsgBoxStyle.YesNo
        title = "Confirm your selection!"   ' Define title.
        response = MsgBox(msg, style, title)
        If response = MsgBoxResult.No Then   ' User chose No.
            Exit Sub
        End If

        'Open Expert Choice
        Call Run(FullName)

        'Close VB.Net!
        frmMain.mi.do("Close All") 'Close all tables without any warning!
        End

    End Sub

    Public Function Copy2Clipboard(ByVal FileNameGIS As String)
        'This function will open ExpertChoiceModel.xls, rewrite its contents by GIS's output (ExpertChoice.dbf) and copy the result to clipboard
        Dim xlApp As New Excel.Application
        Dim books As Excel.Workbooks = xlApp.Workbooks
        Dim bookGIS As Excel.Workbook = books.Open(FileNameGIS)

        Dim ECModel = frmMain.pathName + "ExpertChoiceModel.xls"
        Dim bookModel As Excel.Workbook = books.Open(ECModel)

        xlApp.DisplayAlerts = False

        Dim sheetsM As Excel.Sheets = bookModel.Worksheets
        Dim sheetM As Excel.Worksheet = CType(sheetsM(1), Excel.Worksheet)
        Dim rangeM As Excel.Range = sheetM.Cells

        Dim sheetsG As Excel.Sheets = bookGIS.Worksheets
        Dim sheetG As Excel.Worksheet = CType(sheetsG(1), Excel.Worksheet)
        Dim rangeG As Excel.Range = sheetG.Cells

        '============Test range and write to Excel
        Dim i As Int16
        Dim blah As String
        'blah = "C:\Documents and Settings\Dan Lane\My Documents\Visual Studio Projects\Aquaculture\Data\ExpertChoiceModelB.xls"
        blah = frmMain.pathName + "ExpertChoiceModelB.xls"
```

```
    For i = 1 To 17
        rangeM(4, 4 + i) = rangeG(2, i)
    Next
    bookModel.SaveAs(blah)
    'book.Save()
    '=============Test range and write to Excel

    '===============Copy data to clipboard
    Dim icol, irow As Integer
    irow = sheetM.UsedRange.Rows.Count
    icol = sheetM.UsedRange.Columns.Count
    sheetM.Range(sheetM.Cells(1, 1), sheetM.Cells(irow, icol)).Select()
    sheetM.Range(sheetM.Cells(1, 1), sheetM.Cells(irow, icol)).Copy()
    '===============

    bookModel.Close(False)
    xlApp.DisplayAlerts = True
    xlApp.Quit()
    System.Runtime.InteropServices.Marshal.ReleaseComObject(rangeM)
    System.Runtime.InteropServices.Marshal.ReleaseComObject(sheetM)
    System.Runtime.InteropServices.Marshal.ReleaseComObject(sheetsM)
    System.Runtime.InteropServices.Marshal.ReleaseComObject(bookModel)

    System.Runtime.InteropServices.Marshal.ReleaseComObject(rangeG)
    System.Runtime.InteropServices.Marshal.ReleaseComObject(sheetG)
    System.Runtime.InteropServices.Marshal.ReleaseComObject(sheetsG)
    System.Runtime.InteropServices.Marshal.ReleaseComObject(bookGIS)

    System.Runtime.InteropServices.Marshal.ReleaseComObject(books)
    System.Runtime.InteropServices.Marshal.ReleaseComObject(xlApp)

    xlApp = Nothing
End Function

Public Function Test(ByVal FileName As String)
    Dim xlApp As New Excel.Application
    Dim books As Excel.Workbooks = xlApp.Workbooks
    Dim book As Excel.Workbook = books.Open(FileName)

    xlApp.DisplayAlerts = False

    Dim sheets As Excel.Sheets = book.Worksheets
    Dim sheet As Excel.Worksheet = CType(sheets(1), Excel.Worksheet)

    Dim range As Excel.Range = sheet.Cells
    'range(2, 1) = "success!!"
    'range(2, 2) = "success?"
    range(4, 5) = 222
    range(5, 5) = 333
    range(6, 5) = 444

    Dim blah As String
    blah = frmMain.pathName + "ExpertChoiceModelA.xls"
    book.SaveAs(blah)
    'book.Save()

    '===============Copy data to clipboard
    Dim icol, irow As Integer
    irow = sheet.UsedRange.Rows.Count
    icol = sheet.UsedRange.Columns.Count
    sheet.Range(sheet.Cells(1, 1), sheet.Cells(irow, icol)).Select()
    sheet.Range(sheet.Cells(1, 1), sheet.Cells(irow, icol)).Copy()
    '===============

    book.Close(False)
    xlApp.DisplayAlerts = True
    xlApp.Quit()
    System.Runtime.InteropServices.Marshal.ReleaseComObject(range)
    System.Runtime.InteropServices.Marshal.ReleaseComObject(sheet)
    System.Runtime.InteropServices.Marshal.ReleaseComObject(sheets)
```

```
    System.Runtime.InteropServices.Marshal.ReleaseComObject(book)
    System.Runtime.InteropServices.Marshal.ReleaseComObject(books)
    System.Runtime.InteropServices.Marshal.ReleaseComObject(xlApp)

    xlApp = Nothing

End Function

Private Sub BtnCommunity_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles BtnCommunity.Click
    'Hide me firstly
    Me.Hide()

    Dim SimpleName, FullName As String
    SimpleName = "AquacultureCommunity.ahp"
    FullName = "..\AHP-ExpertChoice\" + SimpleName

    'Do some judge
    Dim msg As String
    Dim title As String
    Dim style As MsgBoxStyle
    Dim response As MsgBoxResult

    msg = "You will open " + SimpleName + "! Be sure it is existent!"
    style = MsgBoxStyle.Question Or MsgBoxStyle.Critical Or MsgBoxStyle.YesNo
    title = "Confirm your selection!"   ' Define title.
    response = MsgBox(msg, style, title)
    If response = MsgBoxResult.No Then   ' User chose No.
        Exit Sub
    End If

    'Open Expert Choice
    Call Run(FullName)

    'Close VB.Net!
    frmMain.mi.do("Close All") 'Close all tables without any warning!
    End

End Sub

Private Sub BtnNGO_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles BtnNGO.Click
    'Hide me firstly
    Me.Hide()

    Dim SimpleName, FullName As String
    SimpleName = "AquacultureNGO.ahp"

    'FullName = frmMain.pathName + "..\AHP-ExpertChoice\" + SimpleName
    FullName = "..\AHP-ExpertChoice\" + SimpleName
    'MsgBox(FullName)

    'Do some judge
    Dim msg As String
    Dim title As String
    Dim style As MsgBoxStyle
    Dim response As MsgBoxResult

    msg = "You will open " + SimpleName + "! Be sure it is existent!"
    style = MsgBoxStyle.Question Or MsgBoxStyle.Critical Or MsgBoxStyle.YesNo
    title = "Confirm your selection!"   ' Define title.
    response = MsgBox(msg, style, title)
    If response = MsgBoxResult.No Then   ' User chose No.
        Exit Sub
    End If

    'Open Expert Choice
    Call Run(FullName)

    'Close VB.Net!
    frmMain.mi.do("Close All") 'Close all tables without any warning!
    End
```

```
    End Sub

    Private Sub BtnProvince_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles BtnProvince.Click
        'Hide me firstly
        Me.Hide()

        Dim SimpleName, FullName As String
        SimpleName = "AquacultureProvince.ahp"
        FullName = "..\AHP-ExpertChoice\" + SimpleName

        'Do some judge
        Dim msg As String
        Dim title As String
        Dim style As MsgBoxStyle
        Dim response As MsgBoxResult

        msg = "You will open " + SimpleName + "! Be sure it is existent!"
        style = MsgBoxStyle.Question Or MsgBoxStyle.Critical Or MsgBoxStyle.YesNo
        title = "Confirm your selection!"   ' Define title.
        response = MsgBox(msg, style, title)
        If response = MsgBoxResult.No Then   ' User chose No.
            Exit Sub
        End If

        'Open Expert Choice
        Call Run(FullName)

        'Close VB.Net!
        frmMain.mi.do("Close All") 'Close all tables without any warning!
        End
    End Sub

    Private Sub BtnIndustry_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles BtnIndustry.Click
        'Hide me firstly
        Me.Hide()

        Dim SimpleName, FullName As String
        SimpleName = "AquacultureIndustry.ahp"
        FullName = "..\AHP-ExpertChoice\" + SimpleName

        'Do some judge
        Dim msg As String
        Dim title As String
        Dim style As MsgBoxStyle
        Dim response As MsgBoxResult

        msg = "You will open " + SimpleName + "! Be sure it is existent!"
        style = MsgBoxStyle.Question Or MsgBoxStyle.Critical Or MsgBoxStyle.YesNo
        title = "Confirm your selection!"   ' Define title.
        response = MsgBox(msg, style, title)
        If response = MsgBoxResult.No Then   ' User chose No.
            Exit Sub
        End If

        'Open Expert Choice
        Call Run(FullName)

        'Close VB.Net!
        frmMain.mi.do("Close All") 'Close all tables without any warning!
        End
    End Sub
End Class
```

```
'*******************************************************************************
'
'module EC2000Contral.vb contains methods to control EC2000 (ExpertChoice 20000)
'
'*******************************************************************************

Option Strict Off
Option Explicit On
Module EC2000Contral
   Public AhpProcess As System.Diagnostics.Process
   Public m_ecID As Boolean
   Public m_ahpprocessID As Integer

   Public Function Run(ByVal AhpFile As String) As Boolean
      'Launching an external program
      'Do not use shell function as classic VB
      AhpProcess = New System.Diagnostics.Process()
      AhpProcess.StartInfo.FileName = AhpFile
      AhpProcess.StartInfo.WindowStyle = System.Diagnostics.ProcessWindowStyle.Minimized
      m_ecID = AhpProcess.Start
      m_ahpprocessID = AhpProcess.Id
   End Function

   Public Sub PasteData()

      If (m_ecID) Then

         AppActivate(m_ahpprocessID)
         If AhpProcess.Responding() = True Then
            AppActivate(m_ahpprocessID)

            SendKeys.SendWait("%GD")
            AppActivate(m_ahpprocessID)

            MsgBox("go to Edit and paste")
            AppActivate(m_ahpprocessID)
            SendKeys.SendWait("%EP")

            'Confirm message box
            AppActivate(m_ahpprocessID)
            SendKeys.SendWait("{ENTER}")
            SendKeys.SendWait("{ENTER}")
            AppActivate(m_ahpprocessID)
         Else
            MsgBox("AHP is not responding,can not paste data", MsgBoxStyle.Critical)
         End If
      End If
   End Sub
End Module
```

```
'******************************************************************************
'
'mainform.vb
'
'******************************************************************************

Imports System.IO 'If you want to use file input or output
Public Class frmMain
    Inherits System.Windows.Forms.Form
    Public Shared mi As Object
    Public Shared PictureBox1Handle As String

    'Dim mapid As Long
    Public Shared mapid As Long
    Dim legendid As Long

    Public Shared OpenResources() As Boolean = {False, False, False, False, False}
    Dim OpenHabitat() As Boolean = {False, False, False, False}

    Public Shared HasSelectResult As Boolean = False
    Public Shared strCreatedTableName As String 'When using created table
    Public Shared strTableName As String
    Public Shared strTempName As String
    Public Shared pathName As String = "C:\Documents and Settings\Yanlai ZHAO\My Documents\Visual Studio Projects\Aquaculture\Data\"
    'Using comparative path seems not working well.
    Public Shared strYear As String

#Region " Windows Form Designer generated code "
......
#End Region

    Private Sub Form1_Load(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles MyBase.Load

        'Create the Map window
        mi = CreateObject("mapinfo.application")
        PictureBox1Handle = PictureBox1.Handle.ToString
        mi.Do("set application window " & PictureBox1Handle)
        mi.Do("set next document parent " & PictureBox1Handle & "style 1")

        'Load the background map
        mi.Do("Open Table """ & pathName & "GMIsland2.TAB"" Interactive")
        mi.Do("Map From GMIsland2")

        mapid = Val(mi.Eval("WindowID(0)")) 'Note, this line's position is very important !!

        'Year Selection
        Dim entry As String
        Dim i As Integer
        entry = "1998"
        cmbYear.Items.Add(entry)
        For i = 1999 To 2002
            entry = Str$(i)
            cmbYear.Items.Add(entry)
        Next i

        strYear = cmbYear.Text

        'Make the Info tool parented to our form for when the user uses that tool
        mi.do("Set Window Info Parent " & PictureBox1Handle)
        mi.do("Set Window Info ReadOnly")

    End Sub

    Private Sub btnExit_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles btnExit.Click
        'mi.do("Close All Interactive") 'Close all tables and prompt you to save or discard changes
        mi.do("Close All") 'Close all tables without any warning!
        End
    End Sub
```

```
Private Sub ToolBar1_ButtonClick(ByVal sender As System.Object, ByVal e As System.Windows.Forms.ToolBarButtonClickEventArgs)
Handles ToolBar1.ButtonClick
    Select Case e.Button.Text
        Case ToolBarBtnGrabber.Text : mi.RunMenuCommand(1702)
        Case ToolBarBtnZoomIn.Text : mi.RunMenuCommand(1705)
        Case ToolBarBtnZoomOut.Text : mi.RunMenuCommand(1706)
        Case ToolBarBtnInfoTool.Text : mi.RunMenuCommand(1707)
        Case ToolBarBtnReset.Text : mi.RunMenuCommand(1701)
        Case ToolBarBtnMarqueeSel.Text : mi.RunMenuCommand(1722)
            'Case ToolBarBtnBoundarySel.Text : mi.RunMenuCommand(1704)
        Case ToolBarBtnBrowseTable.Text
            Dim AfrmBrowseTable As New frmBrowseTable
            AfrmBrowseTable.Show()
        Case ToolBarBtnSetTarget.Text : mi.do("Set Target On")
        Case ToolBarBtnClearTarget.Text : mi.do("Set Target Off")
        Case ToolBarBtnLayerControl.Text : mi.RunMenuCommand(801)

    End Select
End Sub 'ToolBar1_ButtonClick

Private Sub MnuFOpen_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles MnuFOpen.Click
    Dim PostfixTAB As String = ".TAB", PostfixWOR As String = ".WOR"
    Dim FullFileName, FileName As String
    Dim DotTABLastIndex, DotWORLastIndex, SlashLastIndex, DotLastIndex As Integer

    'Mark "|" is used to separate the different file types.
    OpenFileDialog1.Filter = "MapInfo(*.tab)|*.tab|Workspace(*.wor)|*.wor"
    OpenFileDialog1.ShowDialog() 'To open selected file window

    If (OpenFileDialog1.FileName <> "") Then
        FullFileName = UCase(OpenFileDialog1.FileName) 'To simplify other operation
        SlashLastIndex = FullFileName.LastIndexOf("\")
        DotLastIndex = FullFileName.LastIndexOf(".")

        DotTABLastIndex = FullFileName.LastIndexOf(PostfixTAB)
        DotWORLastIndex = FullFileName.LastIndexOf(PostfixWOR)
        'MessageBox.Show("DotTABLastIndex.ToString=" + DotTABLastIndex.ToString)
        'MessageBox.Show("DotWORLastIndex.ToString=" + DotWORLastIndex.ToString)

        'Note the Index starts from 0.
        FileName = Mid(FullFileName, (SlashLastIndex + 2), (DotLastIndex - SlashLastIndex - 1))
        'MessageBox.Show("SlashLastIndex=" + SlashLastIndex.ToString + "  DotLastIndex=" + DotLastIndex.ToString)
        'MessageBox.Show(OpenFileDialog1.FileName.Replace(".TAB", ""))
        'MessageBox.Show(FileName)

        If (DotTABLastIndex > -1) Then 'Open Table
            mi.do("Open Table """ + OpenFileDialog1.FileName + """ Interactive")
            'If this is the first layer, then the next sentence is with problem!!!!
            mi.do("Add Map Auto Layer " + FileName)
        End If
        If (DotWORLastIndex > -1) Then 'Open Workspace by OLE seems not so simple!!!
            mi.do("Run Application """ + FullFileName + """")
        End If
    End If
End Sub 'mnuOpen_Click

Public Function TableOverlay(ByVal tableTag As Object, ByVal tableCutter As Object) As Object
    Dim i, count As Integer
    Dim strLayerName As String

    'Calculate the total layers
    count = Val(frmMain.mi.Eval("MapperInfo(" & frmMain.mapid & ",9)"))

    'Find the layer with the name of tableTag and set it editable
    For i = 1 To count
        strLayerName = mi.Eval("LayerInfo(" & frmMain.mapid & "," & i & ",1)") 'Take layer name
        If (strLayerName = tableTag) Then
            mi.do("Set Map Layer " & i & " Editable On")
            Exit For
        End If
```

```
    Next

    'Select tableTag layer and set it as a target
    mi.do("Select * from " & tableTag)
    mi.do("Set Target On")

    'Select the cutter or the layer corresponding to tableCutter
    mi.do("Select * from " & tableCutter)

    'Cut the nonoverlapping part. Since yield is produced later, it is not appearing in the next sentence.
    mi.do("Objects Intersect Into Target Data ID=ID,Area=proportion(Area)")
End Function

Public Function CombineRow(ByVal strTable As Object) As String
    Dim i, j, count, ColNum As Integer
    Dim strLayerName As String
    Dim strColumnName, ColID, ColYield As String
    Dim ColIDValue As Integer

    'Calculate the total layers
    count = Val(frmMain.mi.Eval("MapperInfo(" & frmMain.mapid & ",9)"))

    'Find the layer with the name of strTable and set it editable
    For i = 1 To count
        strLayerName = mi.Eval("LayerInfo(" & frmMain.mapid & "," & i & ",1)") 'Take layer name
        If (strLayerName = strTable) Then
            mi.do("Set Map Layer " & i & " Editable On")
            Exit For
        End If
    Next


    'Select this layer
    mi.do("Select * from " & strTable)

    'Confirm ID is IDResources, IDHabitat, IDToxicology or IDActivities
    ColNum = mi.Eval("NumCols(" & strLayerName & ")")  'Take the column number
    'ReDim strColumnName(ColNum)
    'Since column 1 is not definitely as ID, next cycle is necessary.
    For j = 1 To ColNum
        strColumnName = mi.Eval("ColumnInfo(""" & strLayerName & """,""col" & j & """,1)") 'Take the column name
        If (strColumnName = "IDResources") Then ColID = "IDResources"
        If (strColumnName = "IDHabitat") Then ColID = "IDHabitat"
        If (strColumnName = "IDToxicology") Then ColID = "IDToxicology"
        If (strColumnName = "IDActivities") Then ColID = "IDActivities"

        If (strColumnName = "YieldR") Then ColYield = "YieldR"
        If (strColumnName = "YieldH") Then ColYield = "YieldH"
        If (strColumnName = "YieldT") Then ColYield = "YieldT"
        If (strColumnName = "YieldA") Then ColYield = "YieldA"
    Next

    'According to the table name to determine the ColIDvalue
    ColIDValue = ColumnIDValue(strTable)

    'Combine all rows (objects) to one
    mi.do("Objects Combine Data " & ColID & "=" & ColIDValue & "," & ColYield & "=" & "sum(" & ColYield & "),Area=sum(Area)")

    'mi.do("Commit Table " & strTable & " Interactive") 'Save the table??

End Function

Public Function ColumnIDValue(ByVal strTable As Object) As String
    'This function uses table nameto determine the value of column ID
    'The file name will affect its ID value; therefore if file name is changed, don't forget to update this function!!

    'For Resources
    If strTable = "HerringDay" Then ColumnIDValue = 1
    If strTable = "HerringNight" Then ColumnIDValue = 2
    If strTable = "U1998Buffer20" Or strTable = "U1999Buffer20" Or _
```

```
      strTable = "U2000Buffer20" Or strTable = "U2001Buffer20" Or _
      strTable = "U2002Buffer20" Then ColumnIDValue = 5

    'For Toxicology
    If strTable = "ChemicalA" Then ColumnIDValue = 1

    'For Habitat
    If strTable = "RockweedBuffer01CutLand" Then ColumnIDValue = 1
    If strTable = "Saltmarsh" Then ColumnIDValue = 2

    'For Activities
    If strTable = "Weir1998Buffer05" Or strTable = "Weir1999Buffer05" Or _
      strTable = "Weir2000Buffer05" Or strTable = "Weir2001Buffer05" Or _
      strTable = "Weir2002Buffer05" Then ColumnIDValue = 1

    If strTable = "FF1998Buffer10" Or strTable = "FF1999Buffer10" Or _
      strTable = "FF2000Buffer10" Or strTable = "FF2001Buffer10" Or _
      strTable = "FF2002Buffer10" Then ColumnIDValue = 2

    If strTable = "U1998Buffer10Cutland" Or strTable = "U1999Buffer10Cutland" Or _
      strTable = "U2000Buffer10Cutland" Or strTable = "U2001Buffer10Cutland" Or _
      strTable = "U2002Buffer10Cutland" Then ColumnIDValue = 5

End Function

Private Sub MnuTLayerControl_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles MnuTLayerControl.Click
    mi.RunMenuCommand(801)
End Sub

Private Sub MnuTViewEntire_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles MnuTViewEntire.Click
    mi.RunMenuCommand(807)
End Sub

Private Sub BtnResources_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles BtnResources.Click
    Dim AfrmResources As New frmResources
    AfrmResources.Show()
    'Should check the index, let ID be IDResources
End Sub

Private Sub BtnHabitat_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles BtnHabitat.Click
    Dim AfrmHabitat As New frmHabitat
    AfrmHabitat.Show()
    'Should check the index, let ID be IDHabitat
End Sub

Private Sub BtnToxicology_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles BtnToxicology.Click
    Dim AfrmToxicology As New frmToxicology
    AfrmToxicology.Show()
    'Should check the index, let ID be IDToxicology
End Sub

Private Sub BtnActivities_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles BtnActivities.Click
    Dim AfrmActivities As New frmActivities
    AfrmActivities.Show()
    'Should check the index, let ID be IDActivities
End Sub

Public Function ExtractTableName(ByVal FullFileName As String) As String
    Dim PostfixTAB As String = ".TAB"
    Dim PostfixWOR As String = ".WOR"
    Dim FileName As String
    Dim DotTABLastIndex, DotWORLastIndex, SlashLastIndex, DotLastIndex As Integer
    FullFileName = UCase(FullFileName) 'To simplify other operation
    If FullFileName.Length <= 0 Then
      MsgBox("Your Full File Name is Empty !?")
      Exit Function
    End If
    SlashLastIndex = FullFileName.LastIndexOf("\")
    DotLastIndex = FullFileName.LastIndexOf(".")
    DotTABLastIndex = FullFileName.LastIndexOf(PostfixTAB)
```

```
        'Note the Index starts from 0.
        FileName = Mid(FullFileName, (SlashLastIndex + 2), (DotLastIndex - SlashLastIndex - 1))
        'MessageBox.Show(FileName)
        Return FileName
    End Function

    Private Sub BtnDestineName_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles BtnDestineName.Click
        Dim count As Integer
        Dim strFullTableName As String 'Include path and extension
        'Dim strTableName As String
        Dim strTableStructure As String
        Dim strStatement As String

        'Calculate the total layers
        'mapid = Val(mi.Eval("WindowID(0)"))
        count = Val(frmMain.mi.Eval("MapperInfo(" & frmMain.mapid & ",9)"))

        'If there is only 1 layer, exit this step
        If (count < 2) Then
            'MessageBox.Show("Only one layer is open? count =" & count.ToString)
            MessageBox.Show("You must upload more layers!")
            Exit Sub
        End If

        'Prepare output filename
        strFullTableName = mi.Eval("FileSaveAsDlg("""", """", ""Tab"", ""Save Table as"")")
        'MsgBox(strFullTableName)
        strTableName = ExtractTableName(strFullTableName) 'Get a short name whith is no path and no ".tab"
        If (strTableName = "") Then
            MsgBox("You don't give a name!")
            Exit Sub
        End If
        'MsgBox(strTableName)

        'Check whether the table is opened or not
        If IsTableExistent(strTableName) = "No" Then
            'Create a table
            'e.g. Create Table "BBB" (ID Smallint,Yield Float) file "C:\BBB.TAB" TYPE NATIVE Charset "WindowsSimpChinese"
            strTableStructure = "(IDResources Integer,IDHabitat Integer,IDToxicology Integer,IDActivities Integer,YieldR Float,YieldH Float,YieldT
Float,YieldA Float,Area Float)"
            'strStatement = "Create Table """ & strTableName & """ (ID Smallint,Yield Float,Area Float) file """ & strFullTableName & """"
            strStatement = "Create Table """ & strTableName & """" & strTableStructure & " file """ & strFullTableName & """"
            'MessageBox.Show(strStatement)
            mi.do(strStatement)
            'Modify the structure of a table, making the table mappable
            mi.do("Create Map For " & strTableName & " CoordSys Earth Projection 1, 103")
            mi.do("Add Map Layer " & strTableName) 'Using "Add" because this is not the first layer
        End If

        'Create a temporary file XXX.tab which will be used in the next extracting process.
        strTempName = "XXX"
        If IsTableExistent(strTempName) = "No" Then
            strStatement = "Create Table """ & strTempName & """" & strTableStructure & " file """ & strTempName & ".tab"""
            mi.do(strStatement)
            mi.do("Create Map For " & strTempName & " CoordSys Earth Projection 1, 103")
            mi.do("Set Map Layer 1 Editable On") 'Now you can operate the created table which is the layer 1
        End If

        'mi.do("Insert into " & strTableName & " values (""3"",21,31)") 'Insert into one line
        'mi.do("Commit Table " & strTableName & " Interactive") 'Save a table
    End Sub

    Public Function IsTableExistent(ByVal strName) As String
        'This function is used to confirm whether the table you are interested in is already open or not
        Dim i, table_count As Integer
        Dim tablenames() As String

        'Determine the number of open tables
        table_count = frmMain.mi.Eval("NumTables()")
```

```
    'Resize the array so that it can hold all of the table names.
    ReDim tablenames(table_count)
    'Loop through the tables
    For i = 1 To table_count
        'read the name of table # i
        tablenames(i) = frmMain.mi.Eval("TableInfo(" & i & ", 1)")
        'If strName table is already existent, then return Yes, otherwise No!
        If strName = tablenames(i) Then
            IsTableExistent = "Yes"
            Exit Function
        End If
    Next
    IsTableExistent = "No"
End Function

Private Sub BtnSelectRegion_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles BtnSelectRegion.Click
    'Check whether you have already pointed a filename to save information!
    If strTableName = "" Then
        MsgBox("You must click Destine Name first!")
        Exit Sub
    End If

    'To select a region (here draw a region), one layer should be editable
    Dim ndx, count As Integer
    Dim strLayer As String

    'Calculate the total layers
    count = Val(mi.Eval("MapperInfo(" & mapid & ",9)"))
    For ndx = 0 To count 'Layer 0 is the cosmetic layer, 1 is the latest added layer
        strLayer = mi.Eval("LayerInfo(" & mapid & "," & ndx & ",2)") 'layer editable? T/F
        If (strLayer = "T") Then 'If layer is editable
            'Open the selection tool
            Dim ASelectTool As New frmSelectTool
            ASelectTool.Show()
            Exit Sub
        End If
    Next
    MsgBox("You must make one layer editable, e.g. the layer you just created its table")
End Sub

Public Function ObjectErase(ByVal TabTarget As Object, ByVal TabEraser As Object, ByVal EraseWhat As String) As Object
    'EraseWhat including EraseOverlay and EraseNonOverlay two types
    'New saved value of TabTarget will transfer back
    Dim i, count As Integer
    Dim strLayerName As String
    Dim strStatement, strKeyWord As String
    Dim strEraserColumnIDName, strTabColumnIDName As String
    Dim ColNum, intEraserColumnIDValue As Integer
    Dim floEraserColumnArea As Double 'numbers with decimal places. Note no float or real
    Dim floEraserColumnYieldR, floEraserColumnYieldH, floEraserColumnYieldT, floEraserColumnYieldA As Double
    'Dim columnIDRes, columnIDHab, columnIDTox, columnIDAct, columnYield, columnArea As String
    Dim TargetColID, ColID, ColYieldR, ColYieldH, ColYieldT, ColYieldA, ColArea As String

    'Check the columns in TabEraser
    ColNum = mi.Eval("NumCols(" & TabEraser & ")") 'Take the column number

    For i = 1 To ColNum

        strEraserColumnIDName = mi.Eval("ColumnInfo(""" & TabEraser & """,""col" & i & """,1)") 'Take the column name
        If (strEraserColumnIDName = "ID") Then ColID = "ID"
        If (strEraserColumnIDName = "IDResources") Then ColID = "IDResources"
        If (strEraserColumnIDName = "IDHabitat") Then ColID = "IDHabitat"
        If (strEraserColumnIDName = "IDToxicology") Then ColID = "IDToxicology"
        If (strEraserColumnIDName = "IDActivities") Then ColID = "IDActivities"
        If (strEraserColumnIDName = "YieldR") Then ColYieldR = "YieldR"
        If (strEraserColumnIDName = "YieldH") Then ColYieldH = "YieldH"
        If (strEraserColumnIDName = "YieldT") Then ColYieldT = "YieldT"
        If (strEraserColumnIDName = "YieldA") Then ColYieldA = "YieldA"
        If (strEraserColumnIDName = "Area") Then ColArea = "Area"
```

```
Next

'Prepare the value which will be used to update TabTarget column, such as IDResources, IDHabitat, IDToxicology, IDActivities etc.
mi.do("Fetch first from " & TabEraser)
'intEraserColumnIDValue = mi.Eval(TabEraser & ".col1")
intEraserColumnIDValue = mi.Eval(TabEraser & "." & ColID)
If (ColArea <> "") Then floEraserColumnArea = mi.Eval(TabEraser & "." & ColArea)
If (ColYieldR <> "") Then floEraserColumnYieldR = mi.Eval(TabEraser & "." & ColYieldR)
If (ColYieldH <> "") Then floEraserColumnYieldH = mi.Eval(TabEraser & "." & ColYieldH)
If (ColYieldT <> "") Then floEraserColumnYieldT = mi.Eval(TabEraser & "." & ColYieldT)
If (ColYieldA <> "") Then floEraserColumnYieldA = mi.Eval(TabEraser & "." & ColYieldA)

'Calculate the total layers
mi.do("Add Map Layer " & TabTarget) 'The TabTarget should be one layer (that is displayed on the map)
count = Val(frmMain.mi.Eval("MapperInfo(" & frmMain.mapid & ",9)"))

'Using Target, erase or intersect
For i = 1 To count
  strLayerName = mi.Eval("LayerInfo(" & frmMain.mapid & "," & i & ",1)") 'Take layer name
  If (strLayerName = TabTarget) Then
    'Select TabTarget layer and set it as a target
    mi.do("Set Map Layer " & i & " Editable On")
    mi.do("Select * from " & TabTarget)
    mi.do("Set Target On")

    'Select the eraser or the layer corresponding to tableCutter
    mi.do("Select * from " & TabEraser)

    'Cutting.
    strStatement = "IDResources=IDResources,IDHabitat=IDHabitat,IDToxicology=IDToxicology,IDActivities=IDActivities,"
    strStatement = strStatement &
"YieldR=Proportion(YieldR),YieldH=Proportion(YieldH),YieldT=Proportion(YieldT),YieldA=Proportion(YieldA),"
    strStatement = strStatement & "Area=Proportion(Area)"

    If EraseWhat = "EraseOverlay" Then
      strKeyWord = "Erase"
    Else
      strKeyWord = "Intersect"
    End If
    mi.do("Set ProgressBars off")
    'MsgBox("Objects " & strKeyWord & " Into Target Data " & strStatement)
    On Error GoTo CloseAllTables
    mi.do("Objects " & strKeyWord & " Into Target Data " & strStatement)
    If EraseWhat = "EraseNonOverlay" Then
      'This step adds ColID of Eraser table to the TabTarget table. From ID, which layers are overlapped can be found
      mi.do("Update " & TabTarget & " Set " & ColID & "=" & ColID & "* 10 + " & intEraserColumnIDValue) 'ColID is the column ID
which is consistent with Eraser.
      'ColID = 0 is possible. In that case, no overlap between ColID

      'ComputerOverlapYield(ColYieldR, floEraserColumnYieldR, newYieldR, newYieldH, newYieldT, newYieldA)
      If (ColYieldR <> "") Then 'It means eraser containing the R term, or R will overlap with TabTarget.tab
        mi.do("Update " & TabTarget & " Set " & ColYieldR & "=" & ColYieldR & " + (Area/" & floEraserColumnArea & ")*" &
floEraserColumnYieldR)
      End If
      If (ColYieldH <> "") Then
        mi.do("Update " & TabTarget & " Set " & ColYieldH & "=" & ColYieldH & " + (Area/" & floEraserColumnArea & ")*" &
floEraserColumnYieldH)
      End If
      If (ColYieldT <> "") Then
        mi.do("Update " & TabTarget & " Set " & ColYieldT & "=" & ColYieldT & " + (Area/" & floEraserColumnArea & ")*" &
floEraserColumnYieldT)
      End If
      If (ColYieldA <> "") Then
        mi.do("Update " & TabTarget & " Set " & ColYieldA & "=" & ColYieldA & " + (Area/" & floEraserColumnArea & ")*" &
floEraserColumnYieldA)
      End If

      'Save the edited table
      'mi.do("Commit Table " & strTableName & "  Interactive")
```

```
            Exit For
          End If
        End If
      Next
      mi.do("Remove Map Layer 1 Interactive") 'Now the first layer shoud be XXX, since it is added latest

      Exit Function
CloseAllTables:
      MsgBox("Your are now in ObjectErase( ). Your program is meeting a problem, the application will be closed!")
      mi.do("Close All Interactive") 'Close all tables
      End

  End Function

  Private Sub BtnDoExecution_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles BtnDoExecution.Click
      Dim ndx, count As Integer
      Dim strLayerName As String

      'Calculate the total layers
      count = Val(frmMain.mi.Eval("MapperInfo(" & frmMain.mapid & ",9)"))
      If count < 2 Then
         MessageBox.Show("You should open more layers!")
         Exit Sub
      End If

      'Check whether you have already pointed a filename to save information!
      If strTableName = "" Then
         MsgBox("You must click Destine Name first!")
         Exit Sub
      End If

      'Check whether you have selected an area!
      mi.do("Fetch First from " & strTableName)
      'MsgBox("The selected layer is " + strLayerName)
      If (mi.Eval("EOT(" & strTableName & ")") = "T") Then
         MsgBox("You must select a region and make it active first!")
         Exit Sub
      End If

      'Confirm whether you want to save the selected info to this first layer
      Dim msg As String
      Dim title As String
      Dim style As MsgBoxStyle
      Dim response As MsgBoxResult

      msg = "Is " & strTableName & " the table you will use to save extracted info ?"
      style = MsgBoxStyle.Question Or MsgBoxStyle.Critical Or MsgBoxStyle.YesNo
      title = "Confirm your output name!"   ' Define title.
      response = MsgBox(msg, style, title)
      If response = MsgBoxResult.No Then   ' User chose No.
         Exit Sub
      End If

      mi.do("Set ProgressBars off")

      'Save the selected region figure for future using. The file name is the selected name + fig.
      'Note, if the same name file is already opened, next sentence will meet problem! Should close the opend file.
      MsgBox("Commit Table " & strTableName & " As """ & pathName & strTableName & "fig.TAB""" & " TYPE NATIVE Charset
""WindowsSimpChinese""")
      mi.do("Commit Table " & strTableName & " As """ & pathName & strTableName & "fig.TAB""" & " TYPE NATIVE Charset
""WindowsSimpChinese""")

      'Cut the island part which is overlapping with the selected area.
      'If data is cleared, this step seems superabundance.
      Dim o3 As Object
      o3 = ObjectErase(strTableName, "GMIsland2", "EraseOverlay")
      'Update the Area column, that is, to include the area value to strTableName.This is the first line of strTableName.tab.
      mi.do("Update " & strTableName & " Set Area = Area(obj, ""sq km"")")

      'Extract info from more than one layer
```

```
Dim strIntersect, strColumnName As String
Dim j, ColNum As Integer
Dim ColID, ColYield, ColYieldR, ColYieldH, ColYieldT, ColYieldA, ColArea As String
For ndx = 2 To count
   'Layer 0 is the cosmetic layer, 1 is the latest added layer, strTableName.
   'If there are some layers which have been uploaded but hided, then the latest added layer is probably not the first layer.

   'Empty next several parameters in case they take the values from last cycle.
   ColYieldR = ""

   ColYieldH = ""
   ColYieldT = ""
   ColYieldA = ""
   strLayerName = mi.Eval("LayerInfo(" & frmMain.mapid & "," & ndx & ",1)") 'Take layer name
   'MessageBox.Show("Layer " & strLayerName & " is extracted! ")

   'Do not let strTableName and GMIsland2 be Target!
   If ((strLayerName <> strTableName) And (strLayerName <> "GMIsland2")) Then
      'Take the common part of layer strLayerName and strTableName

      'Confirm whether ID, Yield and Area are included in the columns of strLayerName
      'Take the column number and then do loop to go through all columns
      ColNum = mi.Eval("NumCols(" & strLayerName & ")")

      For j = 1 To ColNum
         strColumnName = mi.Eval("ColumnInfo(""" & strLayerName & """",""col" & j & """",1)") 'Take the column name
         If (strColumnName = "IDResources") Then ColID = "IDResources"
         If (strColumnName = "IDHabitat") Then ColID = "IDHabitat"
         If (strColumnName = "IDToxicology") Then ColID = "IDToxicology"
         If (strColumnName = "IDActivities") Then ColID = "IDActivities"
         If (strColumnName = "YieldR") Then ColYieldR = "YieldR"
         If (strColumnName = "YieldH") Then ColYieldH = "YieldH"
         If (strColumnName = "YieldT") Then ColYieldT = "YieldT"
         If (strColumnName = "YieldA") Then ColYieldA = "YieldA"
         If (strColumnName = "Area") Then ColArea = "Area"
      Next
      If ((ColID = "") Or ((ColYieldR = "") And (ColYieldH = "") And (ColYieldT = "") And (ColYieldA = "")) Or (ColArea = "")) Then
         MsgBox("Your table about " & strLayerName & " is without enough column !!")
         Exit Sub
      End If

      'Set Target (that is, layer ndx or strLayerName)
      mi.do("Set Map Layer " & ndx & " Editable on")
      mi.do("Select * from " & strLayerName)
      mi.do("Set Target On")

      'Pointing the eraser (that is, strTableName)
      mi.do("Select * from " & strTableName & " into Selection") 'That means every line in strTableName will be a cutter

      'Erase the nonoverlapingping part
      strIntersect = "Objects Intersect Into Target Data "
      strIntersect = strIntersect & ColID & "=" & ColID & ","
      If (ColYieldR <> "") Then strIntersect = strIntersect & ColYieldR & "=" & "Proportion(" & ColYieldR & "),"
      If (ColYieldH <> "") Then strIntersect = strIntersect & ColYieldH & "=" & "Proportion(" & ColYieldH & "),"
      If (ColYieldT <> "") Then strIntersect = strIntersect & ColYieldT & "=" & "Proportion(" & ColYieldT & "),"
      If (ColYieldA <> "") Then strIntersect = strIntersect & ColYieldA & "=" & "Proportion(" & ColYieldA & "),"
      strIntersect = strIntersect & ColArea & "=" & "Proportion(" & ColArea & ")"

      On Error GoTo CloseAllTables
      mi.do(strIntersect)
      'After the intersect, the Target strLayerName.tab was cut by strTableName and only overlapping part was left.
      'It is possible that strLayerName is empty, e.g. selected a blank area. In that case, next combineRow etc. operating will meet problem.
      'Therefore program should judge the state of strLayerName.tab to check it is empty or not!

      'if strLayerName has contents, continue, otherwise go to next ndx?
      mi.do("Fetch First from " & strLayerName)
      'MsgBox("The selected layer is " + strLayerName)
      If (mi.Eval("EOT(" & strLayerName & ")") = "F") Then
         'It means strLayerName is not empty or the begin of the first line is not the end of the last line. "F" means false.
         mi.do("Set Target Off")
```

```
'For each layer, combine multiple lines to one line
CombineRow(strLayerName)

'Using temporary XXX.tab (that is, strTempName.tab) to determine the overlay part between this layer and the strTableName
'--------------------------------------------
'Firstly, clearing XXX.tab
mi.do("Delete From " & strTempName)
mi.do("Commit Table " & strTempName & " Interactive")
'MsgBox("You must save tabe before using Pack Table!")
mi.do("Pack Table " & strTempName & " Data")

'Secondly, copy contents of strTableName to strTempName. Now strTempName=XXX
mi.do("Insert Into " & strTempName & " ( COL1, COL2, COL3, COL4, COL5, COL6, COL7, COL8, COL9) Select COL1, COL2,
COL3, COL4, COL5, COL6, COL7, COL8, COL9 From " & strTableName)

'Thirdly, delete the first row which represents the pointed region
mi.do("Delete From " & strTempName & " where Rowid = 1")

'Fourthly, judge the current table is empty or not. If it is not, extract
mi.do("Fetch First from " & strTempName)

If (mi.Eval("EOT(" & strTempName & ")") = "T") Then 'It means the begin of the first line is also the ended of the last line
   'MsgBox("Only one layer, no necessary to consider overlap!")
Else
   ObjectErase(strTempName, strLayerName, "EraseNonOverlay")
End If
'--------------------------------------------

'Append the selected layer part into the created table
'Take the name of the first column
strColumnName = mi.Eval("ColumnInfo(""" & strLayerName & """,""col1"",1)")
'Take the name of the second column
ColYield = mi.Eval("ColumnInfo(""" & strLayerName & """,""col2"",1)")
'According to the column name, append the information of the selected layer to the result table.
mi.do("Insert Into " & strTableName & " (" & strColumnName & "," & ColYield & ", Area) Select COL1, COL2, COL3 From " &
strLayerName)

'Append the overlay part (eventhough it is empty) into the created table
mi.do("Insert Into " & strTableName & " ( COL1, COL2, COL3, COL4, COL5, COL6, COL7, COL8, COL9) Select COL1, COL2,
COL3, COL4, COL5, COL6, COL7, COL8, COL9 From " & strTempName)

'Save created table
'mi.do("Commit Table " & strTableName & "  Interactive")

'Recover the Target table
'mi.do("Rollback Table " & strLayerName)
  End If
 End If
Next

'Save created table
mi.do("Commit Table " & strTableName & "  Interactive")

'========================================================================
Call OutPutResult3()
'========================================================================

'Export table to DBF file
msg = pathName & strTableName & ".dbf"
mi.do("Export " & strTableName & " into """ & msg & """ Type ""DBF"" CharSet ""WindowsLatin1"" Overwrite")
Exit Sub

CloseAllTables:
  MsgBox("You are now in selecting layer, Your program is meeting a problem, the application will be closed!")
  mi.do("Close All Interactive") 'Close all tables
  End

 End Sub

 Public Function IDIntValue(ByVal Number As Integer, ByVal IDOrder As Integer)
```

```
    'Extract single digital value (IDValue) from Integer Number according to IDOrder which indicates the single digital's location
    'and increases from right to left.e.g. IDValue(709,1)=9; IDValue(709,2)=0; IDValue(709,3)=7
    Dim IDNumber(6) As Integer
    Dim NumberLen, i As Integer

    'IDOrder must be smaller than or equal to the digital number of Number, e.g. IDNumber(12,3) is no meaning, returning -1
    NumberLen = Number.ToString.Length
    If NumberLen < IDOrder Then
      IDIntValue = -1
      Exit Function
    End If

    IDNumber(0) = Number
    For i = 1 To IDOrder
      IDNumber(i) = Int(IDNumber(i - 1) / 10)
      IDIntValue = IDNumber(i - 1) - IDNumber(i) * 10
    Next
  End Function

  Public Function IDCheck(ByVal strIDValue As String, ByVal IDLength As Integer, ByVal IDI As Integer)
    'This function is used to produce a part of SQL selection sentence.
    'strIDValue corresponds to the indexes: IDResources, IDHabitat, IDToxicology and IDActivities
    'IDLength is the length of strIDValue or the component number of corresponding strIDValue,
    'that is. IDLength(IDResources)=5; IDLength(IDHabitat)=4, IDLength(IDToxicology)=3, IDLength(IDActivities)=5
    'IDI is the value we want to check whether it is included in strIDValue,
    'e.g. IDI=2, then strIDValue=231 is included IDI, so is strIDValue=423 etc.

    Dim i As Integer
    Dim D(IDLength), IDValue(IDLength) As String
    Dim strID, DTotal, strOR, strIDI As String
    Dim strWhere As String
    strIDI = IDI.ToString
    strOR = " Or "
    strID = "IDResources"
    strWhere = " Where "

    D(0) = strID 'e.g. 296734
    IDValue(0) = D(0) + " = " + IDI.ToString
    For i = 1 To IDLength
      D(i) = "Int(" + D(i - 1) + "/10)" 'e.g. D(0)=296734 => D(1)=29673
      IDValue(i) = "(" & D(i - 1) & "-" & D(i) & "*10 = " & strIDI & ")" 'e.g. IDValue(1) => (D(0)-D(1)*10) = 2
    Next

    DTotal = IDValue(0) & strOR & IDValue(1) & strOR & IDValue(2) & strOR & IDValue(3) & strOR & IDValue(4) & strOR & IDValue(5)
  End Function

  Private Sub CreateATable(ByVal strName)
    'This sub is used to create a table named strName (e.g. ExpertChoice.tab) which will be used for Expert Choice.
    'Resources: Herring Day, Herring Night, Lobster, Scallops, Urchins
    'Habitat: Rockweed, Salt Marshes, Bottom Structure, Current Flow
    'Toxicology: Chemical A, Chemical B, Chemical C
    'Activities: Herring Weirs, Fish Farms, Lobster Traps, Scallop Drags, Urchin Drags
    Dim strTableStructure As String
    Dim strStatement As String

    strTableStructure = " (YRHerringDay Float, YRHerringNight Float, YRLobster Float,YRScallops Float, YRUrchins Float, "
    strTableStructure = strTableStructure + "YHRockweed Float, YHSaltMarshes Float, YHBottomStructure Float, YHCurrentFlow Float, "
    strTableStructure = strTableStructure + "YTChemicalA Float, YTChemicalB Float, YTChemicalC Float, "
    strTableStructure = strTableStructure + "YAHerringWeirs Float, YAFishFarms Float, YALobsterTraps Float, YAScallopDrags Float,
YAUrchinDrags Float)"

    strStatement = "Create Table """ & strName & """" & strTableStructure & " file """ & strName & ".tab"""
    mi.do(strStatement)
  End Sub

  Private Sub OutPutResult3()
    '2004-01-26 This sub is used to produce results for ExpertChoice.
    'It will produce 2 17-dimension vectors, one for total selected area and the other for unit area.
    '2004-04-22 Allow more than one time calling. The parameter NCall in the OutPutResult2(NCall) denotes the calling number.
    'The result will append to original file. This is way we will try to avoid to create the same table many times.
```

```
Dim strName As String = "ExpertChoice"
Dim strStatement As String
Dim strValue, strValue1 As String
Dim msg As String
Dim strFullTableName As String 'Include path and extension

'Prepare output filename
MsgBox("Please take a name for ExpertChoice!")
strFullTableName = mi.Eval("FileSaveAsDlg("""", """", ""Tab"", ""Save Table as"")")
'MsgBox(strFullTableName)
strName = ExtractTableName(strFullTableName) 'Get a short name whith is no path and no ".tab"
'MsgBox(strName)
If (strName = "") Then
   MsgBox("OutPutResult(couldn) 't create a table name for Expert Choice")
   Exit Sub
End If

Call CreateATable(strName)

'Check row by row of strTableName to consider the effect of the corresponding components of output table
'Judge the current table is empty or not. If it is not, extract
mi.do("Fetch First from " & strTableName)

'According to the column name, append the information of the selected layer to the result table.
'mi.do("Insert Into " & strTableName & " (" & strColumnName & "," & ColYield & ", Area) Select COL1, COL2, COL3 From " &
strLayerName)

'Take the values of the first row
Dim IDResources, IDHabitat, IDToxicology, IDActivities As Integer
Dim ID() As Integer = {0, 0, 0, 0, 0}
Dim YResources, YHabitat, YToxicology, YActivities, YArea, TotalArea As Double
Dim Yield(5, 6) As Integer '5-1=4 means groups and 6-1=5 means maximum component number for each group
Dim i, j, group As Integer 'j means component number for each group
Dim k As Integer 'k is used to judge how many ID are not zero
TotalArea = mi.Eval(strTableName & ".col9")

Do While (mi.Eval("EOT(" & strTableName & ")") <> "T")
   mi.do("Fetch Next from " & strTableName)

   IDResources = mi.Eval(strTableName & ".col1")
   IDHabitat = mi.Eval(strTableName & ".col2")
   IDToxicology = mi.Eval(strTableName & ".col3")
   IDActivities = mi.Eval(strTableName & ".col4")
   YResources = mi.Eval(strTableName & ".col5")
   YHabitat = mi.Eval(strTableName & ".col6")
   YToxicology = mi.Eval(strTableName & ".col7")
   YActivities = mi.Eval(strTableName & ".col8")
   YArea = mi.Eval(strTableName & ".col9")

   ID(1) = IDResources
   ID(2) = IDHabitat
   ID(3) = IDToxicology
   ID(4) = IDActivities
   k = 0
   For i = 1 To 4
      'k represents the overlapped layers in one line, e.g. k=0 represents the first line; k=1 represents the layer without overlapping.
      'We need first determine the k value and then use it to deal with overlapping
      'Since starting from the second line, k must be >0, =1,2,3,...,17.
      If (ID(i) > 0) Then k = k + ID(i).ToString.Length 'ID(i).ToString.Length is a integer number
      'If Id(i) has 3 digital numbers, e.g. 213, then it means 3 layer overlapped in this group
   Next

   'If (k = 1 Or k = 2) Then 'only consider one layer or two pairwise layers
   For i = 1 To 5 'Resources
      If (IDMix(ID(1), i) = "Y") Then 'This line contains Resources layer, i=1 corresponds to HerringDay
         If (k = 1) Then 'This line only contains one Resources layer
            Yield(1, i) = Yield(1, i) + YResources
         End If
         If (k = 2) Then 'This line represents an overlapping of two layers, in which one layer belongs to Resources
```

```
            If (IDResources.ToString.Length = 2) Then Yield(1, i) = Yield(1, i) + YResources / 2
            If (YHabitat <> 0) Then Yield(1, i) = Yield(1, i) + (YResources + YHabitat) / 2
            If (YToxicology <> 0) Then Yield(1, i) = Yield(1, i) - YResources
            If (YActivities <> 0) Then Yield(1, i) = Yield(1, i) - (YResources + YActivities) / 2
        End If
    End If
Next

For i = 1 To 4 'Habitat (almost the same with Resources)
    'If (IDMix(ID(2), i) = "Y") Then Yield(2, i) = Yield(2, i) + (YResources + YHabitat - YToxicology - YActivities) / k
    If (IDMix(ID(2), i) = "Y") Then 'This line contains Habitat layer, i=1 corresponds to Rockweed
        If (k = 1) Then 'This line only contains one Resources layer
            Yield(2, i) = Yield(2, i) + YResources
        End If
        If (k = 2) Then 'This line represents an overlapping of two layers, in which one layer belongs to Resources
            If (YResources <> 0) Then Yield(2, i) = Yield(2, i) + (YResources + YHabitat) / 2
            If (IDHabitat.ToString.Length = 2) Then Yield(2, i) = Yield(2, i) + YHabitat / 2
            If (YToxicology <> 0) Then Yield(2, i) = Yield(2, i) - YHabitat
            If (YActivities <> 0) Then Yield(2, i) = Yield(2, i) - (YActivities + YHabitat) / 2
        End If
    End If
Next

For i = 1 To 3 'Toxico
```

```
            End If
        Next
    Next
    strStatement = "Insert Into " & strName & " Values " & strValue 'Insert one line
    MsgBox(strStatement)
    mi.do(strStatement)
    strStatement = "Insert Into " & strName & " Values " & strValue1 'Insert another line, note: strValue and strValue1
    MsgBox(strStatement)
    mi.do(strStatement)

    mi.do("Commit Table " & strName & " Interactive")
    msg = strName & ".dbf"
    mi.do("Export " & strName & " into """ & msg & """ Type ""DBF"" CharSet ""WindowsLatin1"" Overwrite")

End Sub

Public Function IDMix(ByVal IDValue As Integer, ByVal IDI As Integer) As String
    'This function is used to determine whether IDValue is contained the value IDI
    'If yes, return "Y"; else return "N". e.g. IDMix(123,3) return "Y"; and IDMix(123,4) return "N"
    Dim i As Integer
    Dim IDLength As Integer
    IDLength = IDValue.ToString.Length
    Dim AA(IDLength + 1), BB(IDLength + 1) As Integer

    AA(0) = IDValue
    BB(0) = AA(0)
    For i = 1 To IDLength
        AA(i) = Int(AA(i - 1) / 10)
        BB(i) = AA(i - 1) - AA(i) * 10
        If BB(i) = IDI Then
            IDMix = "Y"
            Exit Function
        End If
    Next
    IDMix = "N"
End Function

Private Sub BtnOthers_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles BtnOthers.Click
    Dim strCreatedFullTableName As String
    'Dim strCreatedTableName As String
    Dim count As Integer
    Dim strUsingThisButton As String

    'Open a created table
    strCreatedFullTableName = mi.Eval("FileOpenDlg("""", """", ""Tab"", ""Open Table"")")
    strCreatedTableName = ExtractTableName(strCreatedFullTableName) 'Get a short name which is no path and no ".tab"
    mi.do("Open Table """ + strCreatedTableName + """ Interactive")

    count = Val(frmMain.mi.Eval("MapperInfo(" & frmMain.mapid & ",9)"))

    'If there is only 1 layer (usually GMIsland2), exit this sub
    If (count < 2) Then
        MessageBox.Show("Only one layer is open? count =" & count.ToString)
        Exit Sub
    Else
        mi.do("Add Map Auto Layer " + strCreatedTableName)
    End If
End Sub

Private Sub DoLegendMaintence()
    'This routine is responsible for showing/hiding the legend, referring to FindZip project
    'associated with the thematic map
    Dim bHasThematic As Integer
    Dim ndx, count As Integer
    'Dim legendid As Long 'already defined in the public shared

    bHasThematic = False
    'Calculate the total layers
    count = Val(mi.Eval("MapperInfo(" & mapid & ",9)"))
    For ndx = 1 To count
```

```
        If (Val(mi.Eval("LayerInfo(" & mapid & "," & ndx & ",24)")) = 3) Then '24 means Layer Infor Type; 3 means selectable
            bHasThematic = True
            Exit For
        End If
    Next

    If (bHasThematic And legendid = 0) Then
        'create legend
        mi.do("Set Next Document Parent WindowInfo(" & mapid & ",12) Style 3") '12 means WIN_INFO_WND, 1 means WIN_INFO_NAME
        mi.do("Create Legend From Window " & mapid)
        legendid = Val(mi.Eval("WindowID(0)"))
    ElseIf (Not bHasThematic And legendid <> 0) Then
        'destroy legend
        mi.do("Close Window " & legendid)
        legendid = 0
    End If
End Sub

Private Sub OpenLegend()
    'This routine is responsible for showing/hiding the legend
    'associated with the added layers

    'Dim bHasThematic As Integer
    Dim ndx, count As Integer
    Dim strStatement As String
    'Dim legendid As Long 'already defined in the public shared

    'Calculate the total layers
    count = Val(mi.Eval("MapperInfo(" & mapid & ",9)"))

    strStatement = ""
    For ndx = 1 To count 'Layer 1 is the final result of extraction
        'read the name of table # i
        If (strTableName <> mi.Eval("LayerInfo(" & frmMain.mapid & "," & ndx & ",1)")) Then 'We don't use the final result layer!
            strStatement = strStatement & " Frame From Layer " & ndx
            'MsgBox(strStatement)
        End If
    Next

    If (strStatement <> "") Then
        'create legend
        mi.do("Set Next Document Parent WindowInfo(" & mapid & ",12) Style 2") '12 means WIN_INFO_WND, 1 means WIN_INFO_NAME
        legendid = Val(mi.Eval("WindowID(0)"))
        mi.do("Create Cartographic Legend From Window " & mapid & " Scrollbars On Portrait Default Frame Title ""#"" " & strStatement)
    Else
        MsgBox("For what layer do you want to create a legend ?")
    End If
End Sub

Private Sub btnCloseLegend_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles btnCloseLegend.Click
    'destroy legend
    If (legendid <> 0) Then
        mi.do("Close Window " & legendid)
        legendid = 0
    End If
End Sub

Private Sub btnThematicMap_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles btnThematicMap.Click
    frmMain.mi.RunMenuCommand(307)
    Call DoLegendMaintence()
End Sub

Private Sub btnOpenLegend_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles btnOpenLegend.Click
    Call OpenLegend()
End Sub

Private Sub cmbYear_SelectedIndexChanged(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
cmbYear.SelectedIndexChanged
    strYear = cmbYear.SelectedItem.ToString
End Sub
```

```
    Private Sub BtnDoECA_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles BtnDoECA.Click
        Dim AfrmDoECAnalysis As New frmDoECAnalysis
        AfrmDoECAnalysis.Show()
    End Sub

End Class
```