A Fisheries Resource Mapping and Management System

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ABSTRACT

A prerequisite for the development of a national or regional management strategy for fisheries and other marine or coastal resources is an inventory of those resources and the subsequent portrayal of that information and data in appropriate formats for review and analysis. The inventory must encompass not only fisheries information, including habitat location, fisheries infrastructure, etc., but also other resource/industry data which may affect the fisheries. Conflicts between users of the coastal zone inevitably arise with "development," e.g., aquaculture versus tourism.

This paper describes relevant techniques of data collection, collation, analysis and display. Such information, together with other alphanumeric and graphic material, including remotely sensed data, is selectively entered into a micro or mini-based Geographic Information System (GIS), the modus operandi of the fisheries resource mapping and management system. The computing capacity of the GIS can, among other functions, serve the additional task of fisheries statistical analysis, one of the subsequent phases in the development of a fisheries management program.

RESUME

Une nécessité préalable au développement d'une stratégie nationale ou régionale d'aménagement des ressources halieutiques et autres ressources marines et côtières est l'inventaire de ces ressources, suivi de la présentation de l'information recueillie en formats convenables pour en permettre la revue et l'analyse. Cet inventaire doit comprendre non seulement les données relatives à la pêche telles l'habitat et l'infrastructure, etc. mais aussi des données sur les ressources/industries qui peuvent affecter les ressources halieutiques et/ou l'industrie de la pêche. Le "développement" de différents aspects des ressources en zone côtière engendre inévitablement des conflits d'intérêts, ex, aquaculture versus tourisme.

Ce document décrit des techniques appropriées relatives à la collection, la collation et l'analyse de données ainsi qu'à la représentation de l'information qui en résulte. Ce genre d'information, ajouté à d'autres données alphanumériques et/ou matériel graphique tel les données obtenues par la télédétection

est selectivement entré dans un système d'information géographique (SIG) fonctionnant à base de micro ou mini ordinateur, le modus operandi du système de cartographie et de l'aménagement des ressources halieutiques. Autre les fonctions à référence spatiale, les capacités de traitement du SIG permettent les analyses statistiques, une phase subséquente dans le développement d'un programme d'aménagement des ressources halieutiques.

INTRODUCTION

According to one of the most recent reviews of the fisheries of the Caribbean sponsored by an international bank (Allsopp, 1984), the fisheries sector has been the focus of nearly 200 studies in the past 40 years. These have primarily been sponsored by the United Nations Development Program/Food and Agriculture Organization (UNDP/FAO) in the field of pre-investment studies and exploratory fishing surveys, and resource surveys and special fisheries projects under the auspices of the West Central Atlantic Fisheries Commission (WECAFC). Additional studies have been conducted by the Caribbean Community (CARICOM), the Inter-American Bank (IDB), the Gulf and Caribbean Fisheries Institute (GCFI), the Overseas Development Agency (ODA) of the U.K., the Commonwealth Fund for Technical Cooperation (CFTC), the Canadian International Development Agency (CIDA), the United States Agency for International Development (USAID) through the U.S. National Marine Fisheries Service (NMFS), the Caribbean Fisheries Management Council (FCMS), and various university groups and institutes.

A recent literature survey of scientific papers relevant to fishery problems in the Lesser Antilles identified 274 publications (Mahon et al., 1985). The authors hoped that the awareness and synthesis of the information would expedite its transition into management advice and planning.

An analysis of the available literature and a degree of familiarity with specific regions of the Caribbean leads to the conclusion that the potential and problems associated with the development and management of the fisheries of the Caribbean in general have been well documented. However, activities, designed to resolve the identified problems, and implement plans to promote the rational development of the fisheries sector, have been minimal. The reasons for this lack of activity have included insufficient funds, lack of trained personnel, inadequate fisheries infrastructure, and the political realities of the Caribbean region.

This paper adopts a holistic approach to fisheries management. So many factors impinge on the fisheries per se, particularly within the multi-national context of the Caribbean, that only an extremely flexible management system can encompass such diverse influences. This remains true regardless of the geographic area of management responsibility, i.e., national, sub-regional or regional.

CARIBBEAN OBJECTIVES

The challenges faced by many of the national authorities responsible for fisheries within the Caribbean may include a requirement for many, if not all, of the following:

1. An inventory of fisheries resources, their distribution and associated habitat. The dynamic nature of these resources compounded by the effects of exploitation, will dictate an equally dynamic system of inventory control and resource mapping to insure the availability of up-to-date information for sector managers.

2. The identification of critical marine/coastal zones and endangered species and the adoption of appropriate conservation measures to ensure sustainable yields of important commercial species.

3. The development of a coastal zone management plan and ethic to anticipate and minimize the effects of multi-user conflicts, e.g., aquaculture, tourism and industry.

4. The identification of sources of pollution, their control, and the requirement for associated contingency plans. The pollution may be ubiquitous, such as oil spills and fecal contamination or a more regional variety, such as Ciguatera.

5. The establishment of an extended economic zone (EEZ) to 200 miles. This extension of jurisdiction compounds the problems of fisheries management because of the vastly increased geographic area involved and the increased probability of trans-boundary fish stock management.

6. The negotiation of fisheries access agreements in relation to a country's 200 mile zone and the concomitant tasks of surveillance and enforcement.

7. The collection of meaningful fisheries statistics within national waters and their subsequent analysis for stock assessment (Pauly, 1984; Caddy and Bazigos, 1985). Trans-boundary fish stocks will dictate a degree of sub-regional and regional cooperation.

8. The establishment of enhanced and coordinated air-sea rescue capabilities as fishing vessels venture further offshore under the impetus of extended fishing zones and increasing mechanization. Offshore mineral exploration and exploitation will predicate such developments.

9. A current inventory of the marine and fishery related infrastructure, including wharf locations, boat repair facilities, ice plants, number and types of fishing boats and gear, etc. Social aspects of the fishing industry, such as a detailed profile of the fishing community, can also be

included in this inventory. Acceptable and, therefore, enforceable management decisions will often depend on such knowledge.

10. A capability to utilize remotely sensed data from satellites, aircraft or helicopters. As with most nations, the acquisition and application of satellite acquired data must be opportunistic; however, aircraft and helicopter imagery is becoming increasingly economic and available.

11. A requirement for technically qualified nationals. Considerable effort has been devoted to this problem including training workshops and courses and an increased role for counterpart training associated with fishery development programs.

12. A program to promote the distribution and consumption of locally caught fresh fish, not only because of its high nutritional value, but also as a means of conserving foreign currency by import substitution. The perceived lowly social status of "fishing" as a career should also be addressed.

The above list, admittedly non-exhaustive, poses a considerable challenge for any potential management system, and currently there are no operational systems which could be considered as a panacea. Two partial remedies, however, are theoretically, if not practically, at hand: the development of regional cooperation and the availability of innovative and relatively inexpensive technology in the form of Geographic Information Systems (GIS).

The WECAFC Committee for the Development and Management of Fisheries in the Lesser Antilles, "The Lesser Antilles Committee," recommended the need to "intensify sub-regional cooperative actions in statistical data collecting systems, training, management and development of fisheries" (Castries, May, 1983). The planned establishment of a Fisheries Secretariat under the auspices of the Organization of Eastern Caribbean States (OECS), sponsored by the International Centre for Ocean Development (ICOD), and the ambitious marine resource program being considered by CARICOM and CIDA, are positive examples of regional initiatives and cooperation.

It is within the context of such fishery development programs and in an effort to respond to the aforementioned functional requirements of a fishery management system, that a marine application for a GIS is proposed, the Marine Resource Information System (MARIS).

THE CANADIAN EXPERIENCE

The coastal zone and continental shelf of eastern Canada is the site of increasing development activity and associated research needs. The availability of, and access to, environmental baseline and resource information within this zone is essential for the resolution of multi-user conflicts,

emergency response requirements and resource management in general. In 1984, the Marine Resource Information System (MARIS) was proposed to accommodate such multi-user requirements. This was accomplished by demonstrating the feasibility of electronically interfacing selected marine and environmental data bases and assessing appropriate cartographic and electronic display systems and their modes of distribution. The Guysborough project was a pilot study designed to test this thesis for a limited geographic area, Guysborough County, Nova Scotia (Butler and MacNeill, 1985).

Many marine environmental and resource inventories, data bases, and other information collections exist (Scarratt et al., 1985). The quantity of information potentially available is increasing at an accelerating rate. Most of the information has limited accessibility and the existence of some of it is not widely appreciated. The requirement to access and interface such information has been recognized for years, as indicated by the partial list of Canadian projects included in Appendix I. These projects and proposals have involved or anticipated an increasing degree of computerization. The Guysborough Project continued that trend.

The rationale for initiating the MARIS program and Guysborough Project, their applications and products, was described in considerable detail in papers presented at the Bedford Institute of Oceanography, "Coastal Zone Mapping in Canada," April 11-12, 1985 (Butler et al., 1985) and at the Canadian Cartographic Association Conference, Fredericton, New Brunswick, June 10-12, 1985 (Butler and MacNeill, 1985). Some of the information is summarized on the following pages and on the basis of the experience gained from the Guysborough Project, we believe that MARIS will continue to be developed in Canada.

OBJECTIVE OF MARIS

An up-to-date inventory of fisheries and other marine and coastal resources, and the subsequent portrayal of that information for review and analysis, is generally considered to be a prerequisite for the development of a national or regional management strategy. It is to this fundamental aspect of a fisheries management system that the merits and relevance of a GIS will be primarily directed. It will become apparent, however, that all of the development requirements previously mentioned can be enhanced to varying degrees by such an automated system.

THE RATIONALE FOR INITIATING THE MARIS PROGRAM IN CANADA

MARIS differs from its predecessors in a number of important aspects:

1. The data bases and information now available are sufficiently numerous and mature to warrant interaction.

2. Because of the multiplicity of data bases, the necessity of

developing Data Base Directories is becoming apparent within individual departments to meet their internal data flow requirements.

3. The technology to develop an effective interface is now available.

4. The technology to produce the information in a variety of formats suitable to the needs of different users is also available, e.g., maps, atlases and display systems.

5. Interfacing data bases, in contrast to integrating them, does not threaten the autonomy of individual data base owners.

6. Organizations such as the Maritime Resource Management Service (MRMS) Inc., are now structurally and technologically capable of providing a brokerage service for clients, be they government or private industry.

In addition to the above rationale, MARIS:

1) Facilitates the coordination, access and flow of information between and within government agencies.

2) Minimizes the duplication of effort in data acquisition, data retrieval, compilation and presentation for internal government requirements and external requests by industry, etc.

3) Allows for and encourages the development of innovative procedures and technology (e.g., synoptic resource maps) which provide support to resource managers.

4) Permits the presentation of selected site-specific information.

5) Emphasizes environmental concerns in sensitive coastal areas.

6) Facilitates public education and involvement in environmental issues.

7) Improves the efficiency and effectiveness of the environmental impact assessment process by allowing experts to concentrate on evaluation rather than simply the acquisition of information.

THE GEOGRAPHIC INFORMATION SYSTEM (GIS)

Because of its complexity, analysis of resource information may involve large volumes of detailed data/information and the investigation of their relationships, hence the utility of Geographical Information Systems (GIS). The essential elements

of an automated GIS are indicated in Figure 1.

There are a number of operational systems now available. The following comments, however, concern the "Geo-Based System," otherwise known by its acronym "STRINGS" (Storage and Retrieval of Information Graphics). MRMS Inc. has gained considerable experience with this system in the past 5 years in all fields of resource management.

The Software

The Geo-Based System permits the collection, conversion and/or storage of both alphanumeric and graphic (mapped) information using a computer. The process of converting graphic information into a form capable of being stored in a computer is termed digitization. Information stored in a computer can be processed, searched, queried, compared with other information and/or displayed in numerous formats using black and white and color display terminals, line printers, pen plotters or other hard copy units. A complete range of data manipulation and spatial analysis software is available and is continuing to be developed to permit use of the system in the widest possible manner of resource information management applications. A GIS is especially suited for processing and handling dynamic data; for example, thematic resource maps. Most GIS systems are similar in configuration, but subtle software differences make some systems more versatile than others. In the Geo-Based System, interfaces have been developed to receive and transmit data from/to other GIS systems. In addition to its mapping function, the computer of a GIS can, of course, be used in a "number crunching" capacity for stock assessment and other statistical needs of fisheries management.

The Hardware

The Geo-Based System operates on a number of processors. It was developed initially on Digital Equipment Corporation (DEC) mini computers and has since been installed on DEC's VAX mainframe and IBM's ubiquitous micro-computer, the IBM PC/AT. The GIS installed at MRMS is a distributed system, i.e., different components of the system can "stand alone" and operate independently from each other (Figures 2 and 3).

The GIS Operation

There are three main functions involved in handling resource information using a GIS:

(i) Input. User documents such as maps, charts, aerial photographs, tabular or textual data are entered into the system via a digitizing table, through keyboard terminals or from existing digital media using a number of specially developed interfaces.

(ii) Processing. Once data are entered into the system, it can

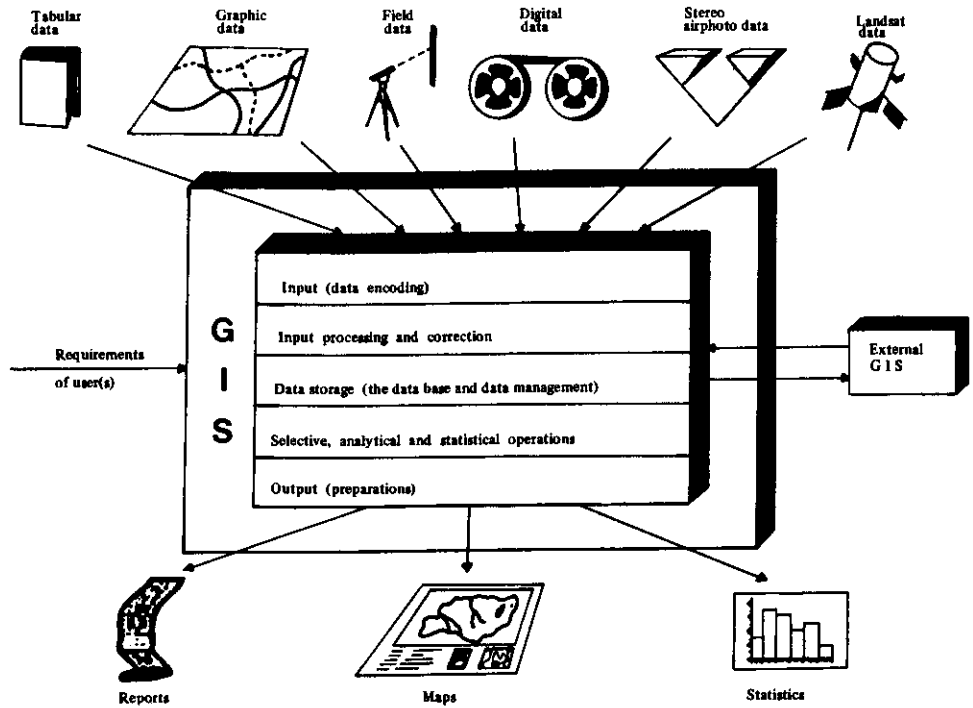

Figure 1. Geographical Information System (from Aalders, H. J. G. L., ITC Journal, 1980-81)

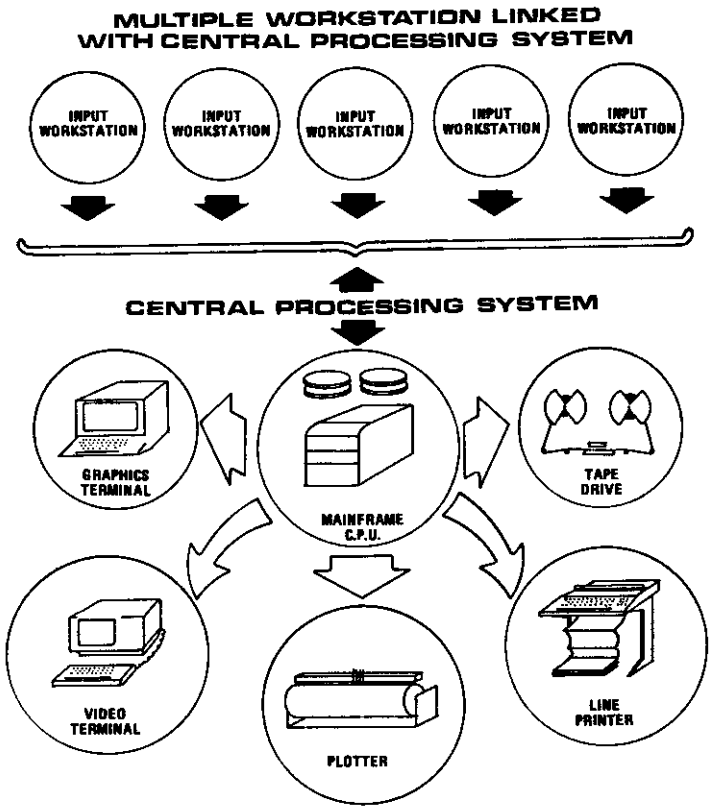

Figure 2. Multiple Workstation linked with Central Processing System.

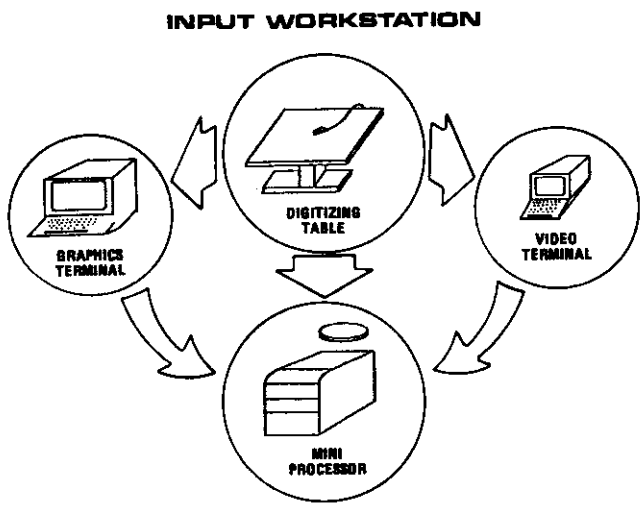

Figure 3. Input Workstation.

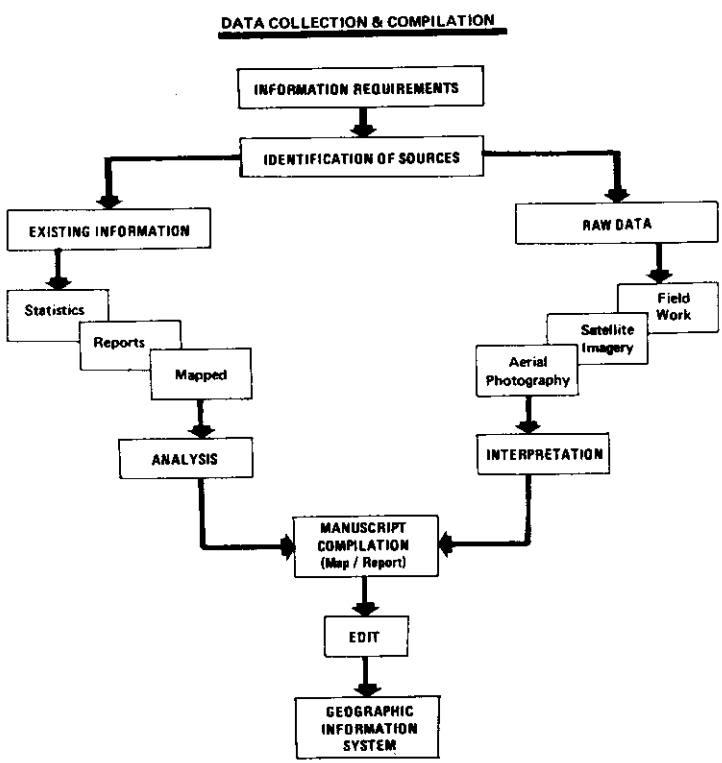

Figure 4. Data Collection and Compilation.

be processed stored, analyzed, synthesized or queried to create an unlimited range of products and to answer questions regarding the data.

(iii) Output. Output can be generated from the system for temporary viewing on a terminal (color or black and white), or as hard copy for distribution or publication using a printer, plotter or other hard copy devices.

THE MARIS PROCESS

In brief, the MARIS process, as demonstrated in the Guysborough Project, includes the following sequential phases:

1. Review of the available data/information bases and the selection/compilation of the desired themes, namely coastal resources (Figure 4).

2. Preparation of an appropriate Data Base Directory with relevant descriptors (abstract, audit trail, etc.).

3. Compilation of a keyword index to the above.

4. Keyboard input of the Directory and keyword index, and digitization of selected graphics appropriately flagged as such in the Data Base Directory. A series of menu driven prompts permit a rapid view of the keyword index and Data Base Directory.

5. Graphic data bases classified according to their coverage, i.e., overview, regional and local.

6. Geographic coverage of the graphic data selected for GIS input indicated on a series of index maps at various scales.

7. Operator choice of two modes of operation:

   (i) A "pre-view" procedure, whereby the selected graphic is portrayed in full color with associated legend.

   (ii) An "analytical" procedure whereby two thematic maps and the appropriate base can be selected to determine possible correlations by simple "overplot" or more complex "overlay" techniques.

The linkage of the various computerized components associated with the Guysborough Project are illustrated in Figure 5.

The Guysborough Network

The array of agencies and assorted data bases constituting the Guysborough network are indicated in Figure 6. The identification of appropriate data bases is a considerable task in itself, and permission to access such information, however

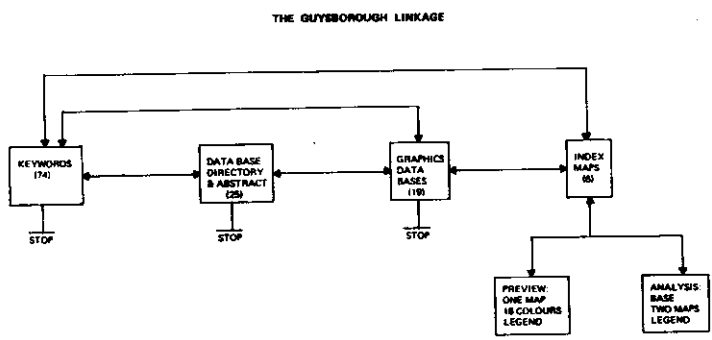

Figure 5. The Guysborough Linkage.

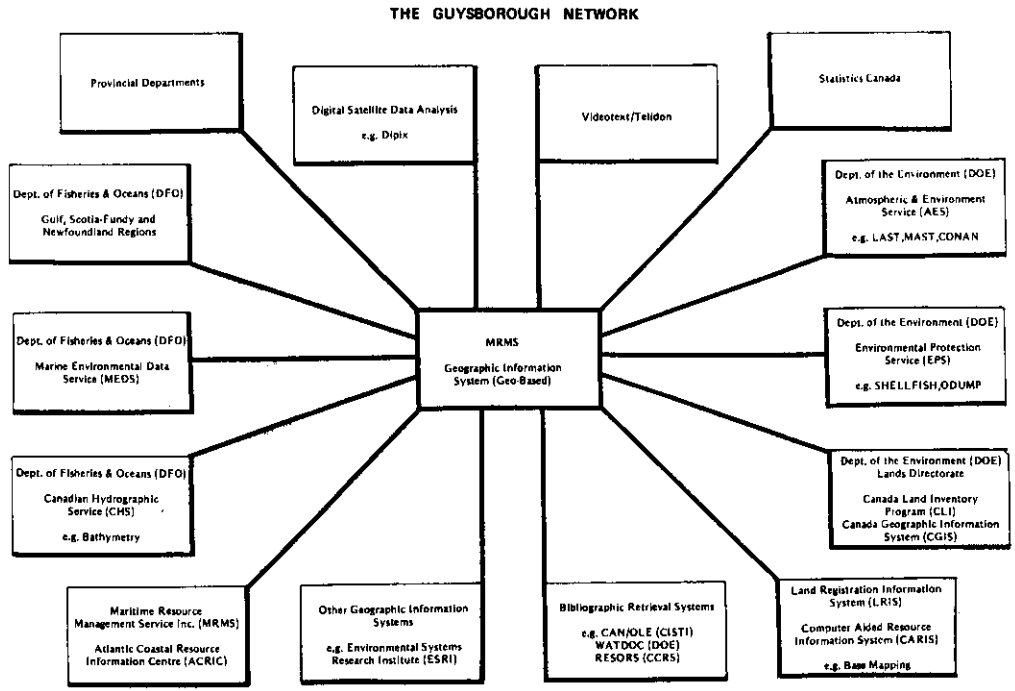

Figure 6. The Guysborough Network.

indirectly, required considerable persistence.

The diversity of the data bases and their formats within the Guysborough network, meant that numerous technical problems had to be addressed, including:

(i) The transfer of alphanumeric data between data bases of differing file structure.

(ii) The transfer of graphic/spatial data (i.e., involving X and Y coordinates) between different Geographic Information Systems.

(iii) The mode of data transfer.

(iv) The transfer of satellite and other digital data, analyzed on an image analysis system, to a GIS.

MARIS PRODUCTS

For those organizations lacking apprropriate technology to access MARIS directly, one or more "brokers" will be required to ensure optimum access to MARIS products. The important point, however, is that MARIS can be "operated" by any one agency, but should be "controlled" by the group of agencies which contribute to the system.

The products from MARIS should include:

1. An inventory of data/information bases in which the subjects and sources are identified (audit trail or lineage report), and when possible, their scientific credibility assessed.

2. A manual describing the MARIS technology, i.e., the array of hardware and software utilized and the associated techniques of access.

3. An updated protocol for participating data base owners.

4. An updated list of hard products which have been wholly or partially derived from MARIS. This would avoid unnecessary duplication of effort.

5. A request procedure for ordering specific products from identified MARIS agencies, i.e., hard products listed in Item 4 above, or original work to be commissioned by the client.

6. A system for quantifying "hit counts," i.e., how many times a particular item of information is utilized.

7. A security protocol to ensure that information obtained from MARIS is not "misused" or "misinterpreted."

8. An acknowledged procedure for accreditation to ensure that persons contributing information to MARIS receive due recognition, i.e., in lieu of publication.

MARIS IN THE CARIBBEAN

The introduction of a MARIS type system as a fisheries resource mapping and management system, for instance under the auspices of the Fisheries Secretariat of the OECS or equivalent CARICOM body, can be carried out in an incremental manner as funds and training personnel permit.

A thorough review of current fisheries literature will be required at the outset. This analysis will determine the form and nature of subsequent data collection, the raw material from which the marine resource mapping program can be initiated.

The collection phase may include a variety of techniques from relatively simple and inexpensive data gathering exercises such as the deployment of personnel to compile field manuscripts, to the complex operations associated with data collection from remote sensing platforms. The information collected can either be stored in the conventional manner on hard-copy maps or it can be entered into the computer of a GIS and stored in a digital form.

The presentation of qualitative and quantitative fisheries information in the form of thematic fisheries maps will permit the following:

- the identification of information gaps and research needs;
- the integration of a wide range of marine information, making it accessible and easily available;
- the presentation of fisheries data, both spatially and temporally, two critical components of a dynamic and mobile resource;
- the communication of simple and complex information to people of a wide range of backgrounds;
- an indication of existing and potential marine activities, hence, assisting in the resolution of conflicts between multiple users of the coastal zone;
- an assessment of the current status of national and regional fisheries.

SUMMARY AND CONCLUSION

Numerous surveys of the status of fisheries and fisheries related information within the eastern Caribbean, in particular, have indicated an almost total lack of, or inadequacy of, thematic or statistical data, at least in a form which can be used for management purposes. There is now an acknowledged requirement for fisheries resource mapping with an initial

emphasis on the collection and presentation of marine information in its most basic form. This exercise cannot be accomplished without the maximum possible involvement and cooperation of Caribbean fisheries personnel. Major sources of fisheries information, rarely utilized to-date, are the fishermen of the region. The use of more sophisticated data acquisition and analysis techniques, if required, will depend on the successful completion of this initial Information Collection phase. This phase and the other three, namely Information Interpretation and Analysis, Presentation and Display of Information, and Training, have been described in considerable detail in other publications, including a cooperative effort by fisheries personnel from OECS nations (Butler, 1983) and a yet to be published FAO manual (Butler et al., in press).

The implementation of a fisheries resource mapping and management system, such as MARIS, will insure that a country's or region's decision makers receive relevant data, in a timely manner and appropriately packaged by technically competent personnel. It can markedly improve government effectiveness in the management of coastal and marine resources and will also result in a greatly improved communications capability among Caribbean nations and their respective marine agencies and departments.

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APPENDIX 1.

LIST OF SELECTED MARINE RESOURCE INFORMATION PROJECTS IN ATLANTIC CANADA

(i) The Coastal Resource Inventory and Mapping Project (CRIMP), 1975. Department of the Environment and Newfoundland Department of Forestry and Agriculture (Warren and Anderson, 1975a and b).

(ii) Nova Scotia Fishery Atlas, 1982. Nova Scotia Department of Fisheries (MRMS/ACRIC, 1982a).

(iii) The Passamaquoddy Marine Resource Pilot Project, 1982. Department of Fisheries and Oceans, Department of Environment (Parks Canada) and New Brunswick Department of Fisheries (MRMS/ACRIC, 1982b).

(iv) Nova Scotia Estuarine and Coastal Resource Inventory, 1982. Department of Fisheries and Oceans and Nova Scotia Department of Fisheries (MRMS/ACRIC, 1982c).

(v) Canadian Atlantic Offshore Fishery Atlas, 1982. Department of Fisheries and Oceans (Scarratt, 1982).

(vi) The Integrated Fisheries Information System on Habitat (IFISH), 1984. Department of Fisheries and Oceans, Habitat Division, Gulf Region (MRMS/ACRIC, 1984).