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An Underwater Science and Resource Database Management System and Proposed Applications to Marine Geographic Information Systems

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AN UNDERWATER SCIENCE AND RESOURCE DATABASE MANAGEMENT SYSTEM AND PROPOSED APPLICATIONS TO MARINE GEOGRAPHIC INFORMATION SYSTEMS

BY

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ABSTRACT

The National Undersea Research Program (NURP) is a federally-funded program that provides scientists with modern in situ technology that allows them to conduct research that goes beyond the constraints of traditional oceanographic methodology. NURP is comprised of five regional centers that administer underwater science, and through the principal investigators that are supported generate a vast quantity of diverse data. This data and information bank consists of the following: raw environmental data, logistical data, locational data, information about the scientists, video and still photograph documentation, and publication information. This paper describes the theory behind and the implementation of a Database Management System (DBMS) designed to deal with the data requirements of the NURP. A relational database design was chosen, and the entities that make up the database were selected from input received from the primary user group of this database - the scientists themselves. The last portion of the paper reviews Geographic Information Systems as a rational extension of DBMS by geographically registering the data summarized above. Several applications of GIS technology in the New England area are reviewed, with focus on the potential for utilization in the marine environment. Two pilot programs that have been initiated within the National Undersea Research Center at the University of Connecticut at Avery Point are discussed with reference to the special advantages that GIS may provide data managers.

ACKNOWLEDGEMENTS

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CHAPTER ONE

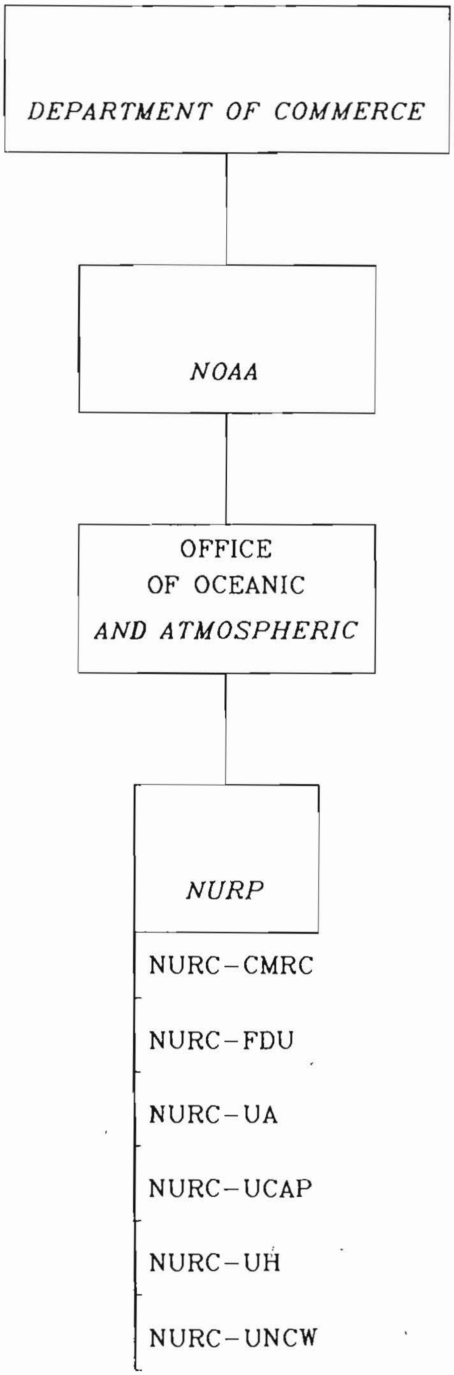
INTRODUCTION

The National Oceanic and Atmospheric Administration's National Undersea Research Program (NURP) is a major funding source for oceanic research. In order to maximize efficiency in the administration of this funding, an "institutional memory" is required in order to eliminate duplicity in funding of scientists, promote cooperation among multi-investigator research teams, and maintain access to the many forms of data collected by the scientists in the field. This paper describes the NURP, and the status of efforts to implement a database management system (DBMS) to address the needs listed above. More specifically, it reports on the efforts to combine this DBMS into a Geographical Information System (GIS) that will provide the ability to map and model the information in an accurate spatial context.

Overview of The National Undersea Research Program

NURP supports in situ investigations in the oceans and large lakes of the world. The program is designed to place scientists safely underwater to conduct experiments not possible within the limitations of traditional laboratory or ship-based research. NURP is managed by the Office of Undersea Research in Rockville, MD and the research community gains access to the program through five regional national undersea research centers (NURCs) (Figure 1). These centers are primarily located at major universities

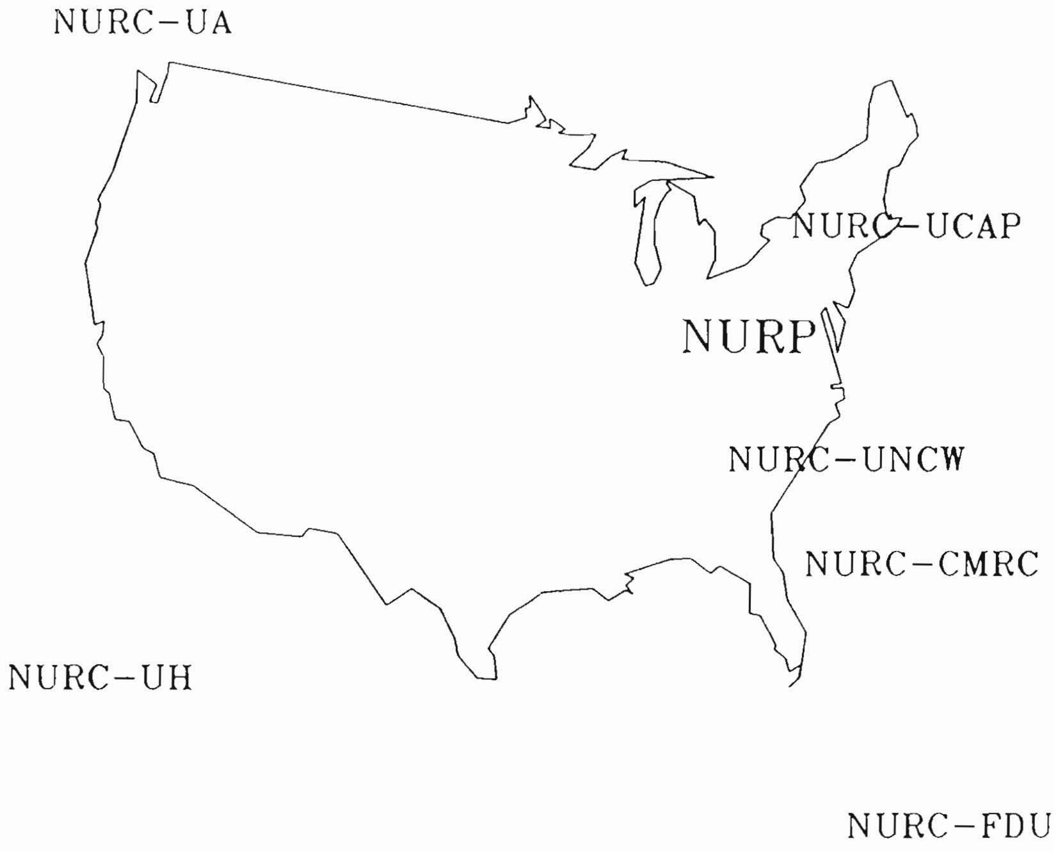
FIGURE 1
ORGANIZATION OF NURP



which provide the infrastructure to pass funding from NOAA to the scientists. The five undersea centers are located at the universities of Connecticut, Hawaii, North Carolina (Wilmington), Fairleigh Dickinson University, and a non-university based center at the Caribbean Marine Research Center in Riviera Beach, Florida (Figure 2). A sixth center is planned to support west coast research needs. Synopses of each of the five centers are presented in Appendix A.

As major funding sources, the NURCs maintain annual cycles based upon solicitations for research (Requests for Proposals) that canvass the research community for science proposals. Preproposals are sent in, critiqued by the NURCs with respect to the feasibility of the research and any potential for collaborative or interdisciplinary projects with other investigators. These proposals are then sent out for outside review. This is followed by a panel review of five or six experts brought in from around the country to assess the quality of the science. Meritorious proposals are then granted the type of in situ research support requested and a lesser degree of funding for science support. In this way, NURP provides the focal point for the underwater research requirements of government, academia, and industry. The majority of science support is obtained via co-funding from traditional granting agencies such as the National Science Foundation, Sea Grant, Office of Naval Research, United States Geological Survey, the Minerals Management Service, and the business community.

FIGURE TWO
LOCATION OF NURCS



Research activities are aimed at increasing our knowledge of the structure and processes of the global ocean. Ultimately, armed with an understanding of how physical, chemical, biological, and geological processes control marine environments, informed decisions can be made to improve the management of marine resources. General research themes include: 1) Biological Productivity and Living Resources, 2) Coastal Oceanic and Estuarine Processes, 3) Pathways and Fates of Material and Energy in the Ocean, 4) Global Oceanic Processes, 5) Ocean Lithosphere and Mineral Resources, 6) Ocean Technology, and 7) Diving Safety and Physiology. The diversity of specific research priorities supported by NURP is listed in Appendix B.

The nature of the in situ support provided by the NURCs is varied and largely depends upon the regional research needs of the scientists. Manned submersibles, unmanned remotely operated vehicles (ROVs), a saturation habitat, mixed gas and conventional scuba comprise the arsenal of high technology support provided by NURP. The depth range of this technology extends from shallow coastal waters to depths of over 4000 meters. Examples and capabilities of the diverse research platforms are provided in Appendix C.

The Need for Research Database Management within NURP

In order to provide the "institutional memory" for the NURP a coordinated DBMS is required. This DBMS must address not only the information needs of the NURP, but also those of the scientists supported. At a programmatic level, NURP and its satellite NURCs collect, measure, and generate vast quantities of data that varies depending upon three principal factors. The most significant of these is the research theme being addressed by the principal investigator (PI) supported by NURP, which dictates the nature of the data collected. The specific themes supported by NURP are extremely diverse, and each research theme has it own suite of significant parameters to measure. Examples of the diversity of information are included in Appendix A. The second variable is the type of platform or in situ methodology being used by the PI, which affects not only the type of data collected, but also determines the means by which it is collected. The third factor is the different management strategies and operational credos of each of the NURCs. This third variable refers to the various levels of data "micromanagement" imposed by each of the NURCs, for example, at NURC-UCAP it has been left primarily in the hands of the investigator, while at NURC-UHI, it is totally managed by the center, with the PI receiving only copies of the information collected. This variability in data management should be addressed by the Office of Undersea Research, which should establish a minimum set of criteria that all of the NURCs will collect, maintain and share in a common format in order to facilitate sharing of the database.

At an individual project level, the data collected by PIs exhibits many diverse characteristics as well, including variety, volume and scale (Michener, 1986). The variety, once again, is research theme dependent, but may contain physical and chemical parameters (e.g. water temperature, current velocity, sediment grain size, measures of contaminant loadings etc.), qualitative descriptors of underwater habitats or physiographic regions (e.g. canyons, reefs, ledges, shoals etc.), and quantitative measures of ecosystems (species abundance, diversity, etc.). In addition, characteristics of community dynamics (e.g. predator-prey interactions, competition, recruitment success), organism response to changing environmental conditions, and other complex behavioral data are routinely collected. The information collected is derived from small projects that collect discrete data from site-specific locations, to large multidisciplinary projects that collect many different types of data. The data collected varies spatially from site-specific manipulative experiments that functionally occupy a few meters to large scale survey projects that attempt to address whole ecosystems (e.g. Georges Bank, Long Island Sound).

Database Management Design and Implementation

To meet the needs at both the programmatic and project levels requires a powerful, yet flexible DBMS. Management Information Systems (MIS) theory suggests the utility of a relational database model to deal with multi-level data management (Posmentier, 1977). Research database theory and the relational database model are described in Chapter Two.

The specific pieces of information held within a database are termed the "attributes" or "entities" (Codd, 1970). In order to define the most useful suite of attributes that would address both programmatic and project level needs, a questionnaire was distributed to the largest group of potential users, the scientists funded by NURP. This survey and results are presented in Chapter Three.

Geographic Information System Integration

Finally, a standard format for easy data exchange among the user groups must be recognized and made easily available. The development of Geographic Information Systems (GIS) as a means to organize, analyze, and present data in a spatial context has exhibited a meteoric growth curve in the past decade. Chapter Four describes these systems and lists applications and the initiation of the use of these systems in the marine environment. Diverse, terrestrial applications have been assembled by various managers within branches of local, state, national, and international governments. To date, however, only a handful of attempts are being made by managers of science programs to transfer this land-based technology to the marine environment. GIS's represent the cutting edge of data management by providing a spatial context to serve as the base upon which to register all of the other types of data collected in the marine environment. Chapter Five describes two pilot projects that are being partially supported by NURC-UCAP.

CHAPTER TWO

RESEARCH DATABASE MANAGEMENT

Overview of Research Data Management

Research data management refers to a task whereby various tools (computers, statistics etc.) are used to organize, store, and retrieve, integrate, and analyze research data. Data entry, quality assessment, documentation, and statistical and graphical analysis are all tasks that fall under the broad definition of data management (Table 1.)

Table 1. Research database management activities

TASK	EXAMPLE
Experimental Design	Randomized Complete Block
	Systematic Survey Sampling
Data Entry	Forms Design
	Program Design
	Manual/Electronic Data Entry
Quality Control	Entry Error Checking
	Range Checking
	Statistical/Graphical Outliers
Documentation	Database catalogs
	Program Documentation
Storage and Retrieval	Database Additions
	Device Dependent Programs
Security	Password Protection
	Multiple Storage Locations
File Manipulation	Unit Conversion
	Sort
	Merge
Analysis	Statistics
	Graphics
	Modeling

The level of management a database receives is dependent upon several factors including project longevity, data complexity, degree of data utilization, granting agency requirements, and funding levels (Michener, 1986). Sophisticated data management is required for more complex, multi-investigator projects that typically generate larger volumes of data that must be integrated over various spatial and temporal scales (Date, 1975; Martin, 1976). This latter requirement mandates strict quality control and unified database structure. Such a scenario applies to NURC-UCAP, a multifaceted, multi-investigator, multi-agency program (Table 2).

Defining the Need for Database Management

Implementing a database management system (DBMS) is a time and money intensive endeavor, and therefore, the need for such a system should be well recognized within the user community. The following is a list of functions (from Risser and Treworgy, 1986) that a well developed database can accomplish and should be considered prior to the expenditure of resources to develop and implement a such a database. The purpose(s) of a DBMS should be to:

1. maintain a research memory by providing an organized means for capturing the results of a research program. This is essential for a research program involving many diverse investigators in order to instill a sense of institutional memory. It is also important when studying long-term ecological or environmental phenomena that may outlive a single investigator's tenure.

2. encourage the transfer of valuable data that is sequestered in file cabinets to an active working data file.

3. motivate more rigorous scrutiny of data sets, as often times the act of contributing to an existing database prompts a more thorough evaluation of the data.

4. permit the convergence of multiple data sets that can be utilized to address a specific topic or research question spatially or systematically. This convergence is contingent upon the development of a database structure has taken this objective into account.

5. provide for multi-investigator access of data sets. This is particularly useful for basic environmental and ecological variables.

6. reduce the time spent by investigators in locating, compiling, and synthesizing data, thereby increasing the time available to analyze and test hypotheses. Accessible databases also eliminate costly duplication of effort by making existing information available to future researchers.

7. increase the insight into and comprehensiveness of the research questions being asked or to expand the possible approaches to addressing resource management problems.

8. present persuasive arguments in the decision-making process by providing easily comprehensible data about complex interactive ecological processes that occur over long periods of time.

9. be able to incorporate ecological data from rapidly changing field observations into real-time modeling programs.

Table II. SUMMARY OF NURC-UCAP OPERATIONS 1984-1988.

YEAR	REGION	DIVE SYSTEM	NUMBER OF DIVES	NUMBER OF PARTICIPANTS	NUMBER OF AFFILIATIONS
1984	I	MERMAID	29	23	9
		RECON IV	27		
1985	I	JSL	55	34	18
		MINIROVER	31	6	3
	III	JSL	43	33	14
1986	I	DELTA	46	17	9
		JSL	9	11	4
		SCUBA	22		
		R/V OCEANUS		9	4
		MINIROVER	43	5	2
	II	DELTA	18	11	4
		JSL	8	11	8
		MINIROVER	4		
	III	JSL	37	31	11
1987	I	DELTA	130	69	10
		JSL	56	43	18
		MINIROVER	44	6	4
		PHANTOM S	6	2	1
		SCUBA	27		
	II	DELTA	101	51	13
		JSL	26	26	12
		MINIROVER	4	2	1
	III	MINIROVER	75	16	6
		PHANTOM S	17		
1988	I	DELTA	81	51	6
		JSL	11	22	4
		MINIROVER	18	3	
		PHANTOM S	3	1	1
		SCUBA	557	20	5
	II	DELTA	46	15	8
		JSL	10	12	6
		MINIROVER	91	6	3
		SCUBA	152	5	1
	III	JSL	67	84	39
		MINIROVER	80	4	3
		PHANTOM S	25	2	1
1989	I	JSL	91	100	34
		DELTA	30	32	24
		NITROX	104	21	4
		MINIROVER MK I	17		
		MINIROVER MK II	27		
	II	JSL	2	12	4
		DELTA	47	19	11
		NR-1	1	2	2
		MINIROVER MK II	56		
		PHANTOM 300	21		
	III	MINIROVER MK I	82		
		MINIROVER MK II	67		

TABLE II. (CON'T) SUMMARY OF NURC-UCAP OPERATIONS 1984 - 1988.

	TOTALS			
YEAR	MANNED SUB	ROV	SCUBA	PARTICIPANTS
1984	29	27	0	23
1985	98	31	0	73
1986	118	47	22	95
1987	313	145	51	211
1988	215	217	709	186
1989	177	270	104	240
GRAND TOTALS	946	737	892	828

Defining the Need for a NURP Research DBMS

The decision to implement a database management system will be based on meeting some or all of the above objectives. The above list of objectives/functions of a research database contains several points that directly coincide with the needs of NURP's database management. The following is lists each of the functions of a DBMS as spelled out above, and then provides an example of how that function applies to the needs of NURP.

> Objective One: to maintain a research memory - NURP and its predecessor, Manned Undersea Science and Technology (MUST) has been in existence since 1972 with the level of research increasing yearly. Throughout the history of this program, data has been collected. Without an adequate means to store this information and make it available to users, this information, and hence, the "institutional memory" of NURP will be lost.
>
> Objective Four: to permit convergence of data sets - NURP is comprised of five centers, if common environmental parameters were sampled and entered into a database a fairly substantial baseline of information could be collected. This also applies to researchers supported by a single NURC, if similar projects are conducted the results could be merged to form a more robust dataset.
>
> Objective Five: to provide easy access to data used by more than one investigator - NURP encourages multi-investigator projects to address complex ecological problems. The ability to query and access "key words" would facilitate these cooperative research efforts.
>
> Objective Seven: to increase insight into and comprehensiveness of research questions - many long-term NURP-funded projects could benefit from comparisons over time that could indicate trends or patterns in resource allocation and utilization.
>
> Objective Eight: to present persuasive arguments in the decision-making arena - NURC has recently been called upon by members of Congress and the fishing industry to provide data with regard to several important ecological and environmental issues (e.g. mass coral bleaching, the impacts of ocean dumping on benthic habitats).

Based upon the fulfillment of these criteria implementation of a database management system within NURP is warranted and needed.

The next level of inquiry is at what geographic level this database could most effectively be implemented, and in the case of NURP two levels are possible - the national or regional. A recent workshop sponsored by the University of Rhode Island's Center for Ocean Management Studies (COMS) addressed the issue of marine database management and the scales of implementation that would be most effective on the local, regional or national level.

Coastal and Estuarine Data in Disarray - Development of a Data Management Model that Works

In July, 1989 COMS convened a workshop to address the question of database management in the coastal oceans and estuaries. The major issue of the workshop was: how can scientists, decision-makers, and data managers deal with the various sources of data systems, know how to use the available data and how do/should these data (and systems) relate to one another. Further rationale for the meeting was summed up in the background provided for the workshop:

> "Even though the coastal and estuarine areas contain the most productive fisheries, are highly utilized tourist and recreational areas, are used for waste disposal, and are areas of aesthetic significance for

much of our population, due to the lack of a coordinated source of information we don't even know for sure that we are utilizing all of the relevant information available on these areas nor that we are collecting those data of long-term significance".

The workshop was organized around group sessions which dealt with the above issue on the local, regional and national levels. Each group was given a problem that required access to ocean data and asked to make recommendations regarding database management systems. Specific topics to be included was the identification of database systems that worked, those that did not, what were the desirable criteria, how could these systems be made responsive to users, how should the data be distributed and how could these systems be integrated and enlarged to generate global data sets. The groups then reconvened to make specific recommendations concerning the issues framed within the categories that would be useful for legislative officials, resource managers, and inter/intra agency data managers.

The results of the workshop strongly suggested the need for data centers to address the data needs of scientists working in coastal oceans and estuaries. Similarly, this independent endorsement of the regional concept lends support to the notion that national research database needs are best served by an integrated network of regional centers. Thus, extrapolation of the results of the COMS workshop, suggests that the most logical and effective means to implement a NURP research database is through the regional NURCs. This network should receive guidance and minimal data requirements from the national level which should also function as the catalyst and conduit for data exchange (Figure 3).

Another important consideration in the decision of scale of DBMS implementation is the relationship between the level of sophistication of data output products, (e.g. data tables, reports, maps etc.), the frequency of demand typical natural resource groups, and the number of potential users (Hardy, 1982). These relationships, modified to encompass the users associated with NURP are presented graphically in Figure 4A. Figure 4B suggests that a regionally-based DBMS falls as the mid-point in the continuum of potential users, and as such could best respond "up" or "down" a hypothetical vertical scale. This concept is termed "vertical data integration" and presents several potential benefits including: a more diverse and comprehensive data base for decision making, cost prevention through prevention of data duplication, and greater cooperation between data users (Wilson, 1979; Norman, 1982). The higher level of sophistication of the output products required at the federal government agency level represents the processing of raw data into more general information required by upper level resource managers.

FIGURE THREE
NURP PROPOSED DATABASE NETWORK

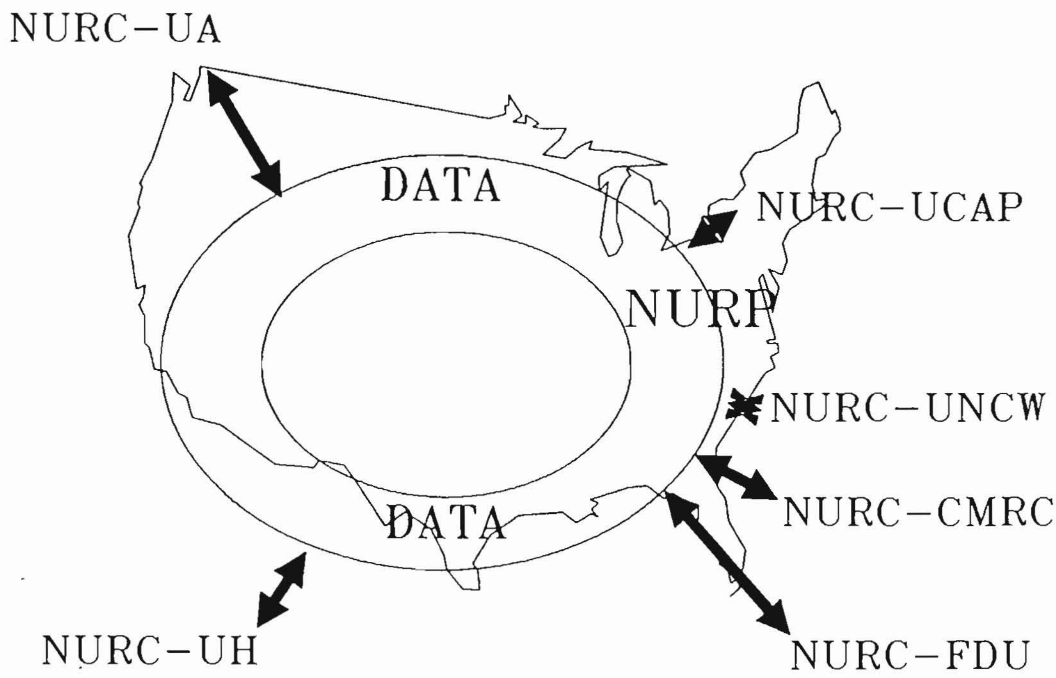
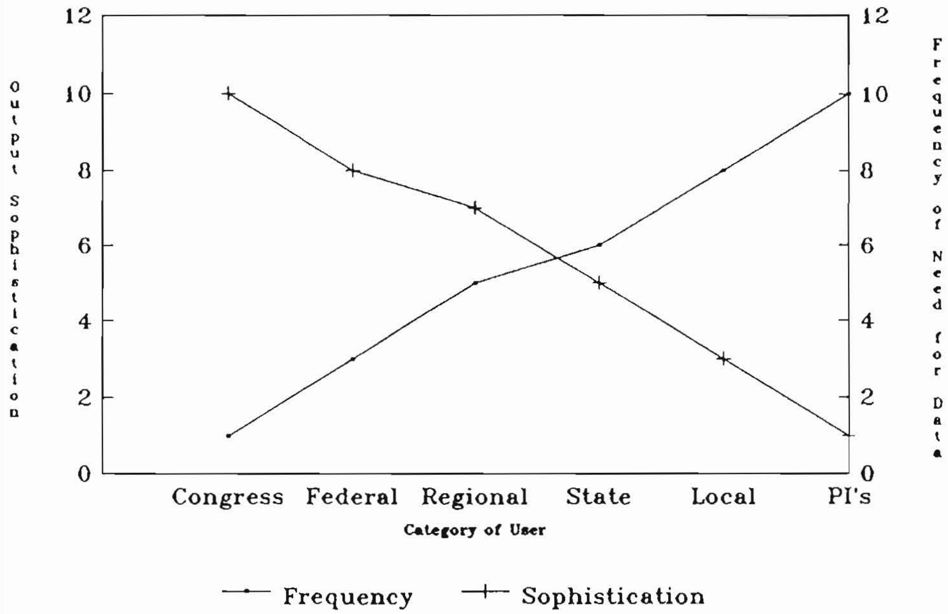
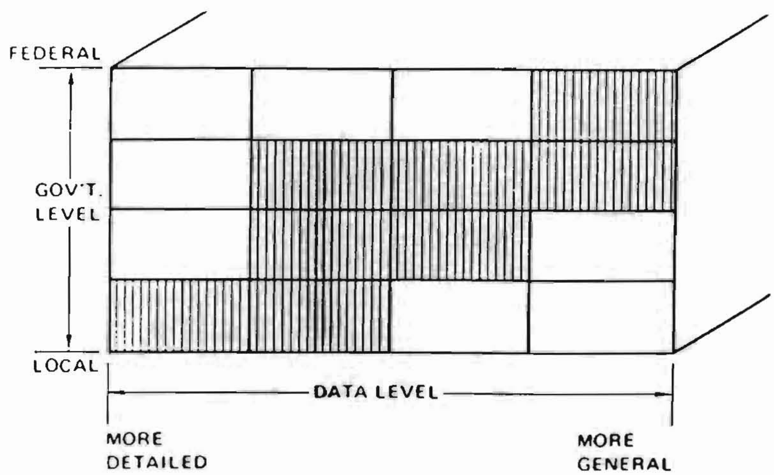


FIGURE 4
DATABASE SOPHISTICATION VS USERS



A



B

Definition of a Regional Underwater Resource DBMS

The following outlines the steps pursued to define a regional DBMS for the NURC-UCAP. The development of such a DBMS that is responsive to the needs of the user community requires a multistep procedure: first, to identify the user groups of the DBMS; second, to ensure that the DBMS addresses the needs of these users; and third, to guarantee that the users are educated about the system and have easy access to the all of the data in some coordinated format (Hardy, 1982). For the NURC-UCAP, this paper proposes to define the range of the user community as the PI's involved with the collection of the data, other NURC's, and resource management agencies involved with the collection of ocean data. Each of the user groups will have a different set of data requirements that will range from specific data needs of the PI's to the more general information useful at the policy level. The distinction between raw scientific data and processed information useful in the decision-making process must be emphasized. Information is distilled via statistical analysis and interpretation by the scientist. Another potential user of information are decision makers involved in the political process and resource management decisions, such as members of the U. S. Senate and House of Representatives. The final user of the data or information is the general public within each of the NURC's geographic regions. These encompass the majority of past, and potential users of underwater data.

For the sake of database design, therefore, it is assumed that the needs of all other users will fall within, or can be processed from the data collected by the PI's. This assumption is based on the fact that the data collected by the PI's represents the most rigorous and complete datasets. Defining the range of these data required by the scientists working in the field is addressed in Chapter Three.

CHAPTER THREE

DATABASE SURVEY AND DESIGN

Database Survey

Having identified the Principal Investigators (PI's) as the target users of the DBMS, the next step was to ascertain the range of data that would be most useful to this group. In order to quantify these specific data needs, a survey instrument was developed to canvass the PI's within the regional limits of the NURC-UCAP. This survey was conducted via distribution of a self-administered questionnaire mailed to the scientists supported by NURC-UCAP asking them to check the types of data that they would most like to see and utilize in a DBMS. Once these variables or "entities" were identified, they could then be used to design the database that would satisfy the objectives/functions listed in Chapter Two that are germane to the NURC-UCAP scientists. The means by which the data comprising each of the entities would be collected would be in a form that would accompany a standard report form, a "Quick-Look" report, which must be completed by every NURC-UCAP PI prior to departing the research vessel (see Appendix B).

The range of data that would be included within the various datasets was determined by the total amount of data available to the PI on every research cruise and manned or unmanned submersible dive within that research mission. All of these data entities comprised the checklist that was circulated to active researchers supported by NURC-UCAP. The checklist was mailed to the PI's along with a short memorandum describing the rationale for the checklist. In order to ensure that the responses came from PI's who were especially interested in the concept of database design, no Self-Addressed, Stamped Envelope was included, and no follow-up phone calls were made to prompt completion of the survey instrument. The number of investigators queried totalled 100, fortythree of whom returned the questionnaires, which is an exceptionally high rate of return. Of the 43 responses, 41 indicated that they thought such a data base was a good idea (a summary of responses and comments is included in Appendix E).

The checklist is copied below, with the total number of responses for each entity and percentage of the 43 responses noted on the checkoff line. The term "key word" was used to refer to database entity.

CHECKLIST OF POTENTIAL KEY WORDS
WITH NUMBER AND PERCENT OF RESPONSES FOR EACH

Number	Percent	Keyword
22	51.2	Research Project Number
23	53.5	Chief Scientist
21	48.8	Address
20	46.5	Telephone Number
16	37.2	Research Leg Number
19	44.2	Dive Number
21	48.8	Date
22	51.2	Location
20	46.5	Latitude/Longitude of Dive Site
19	44.2	Loran C Coordinates
11	25.6	Start Time of Dive
12	27.9	Video Tape Number
15	34.9	Video Tape Format 3/4", 1/2", 8mm
10	23.3	Still Photos, Number of Frames
20	46.5	Depth Range of Dive
5	11.6	Predive Sampling Activity
14	32.6	Observer Number 1 (Fore sphere)
12	27.9	Observer Number 2 (Aft compartment)
12	27.9	Submersible Pilot
16	37.2	Water Temperature
15	34.9	Current, Velocity and Direction
17	39.5	Visibility
14	32.6	Transmissivity
12	27.9	Comments
11	25.6	Loran Coordinates of Bottom Fixes
6	14.0	Comments
22	51.2	Samples Collected and Tasks Performed
18	41.9	Box or Punch Cores
18	41.9	Suction Samples
12	27.9	End Time of Dive
9	20.9	Duration of Dive
21	48.8	Type of Dive
17	39.5	Midwater
20	46.5	Benthic
15	34.9	Substratum Features (Check all that apply)
17	39.5	Smooth, Sand/Mud Bottom
16	37.2	Thin Sediment Veneer Over Hard Bottom
16	37.2	Cobble

	17	39.5	Rock Outcropping
	16	37.2	Boulders
	17	39.5	Vertical Walls
	17	39.5	Flat Bottom
	14	32.6	Shallow Slope
	14	32.6	Steep Slope
	14	32.6	Estimated Slope Angle
16		37.2	Organisms/Objects Recorded (Check all apply)
	16	37.2	Particulate Matter
	15	34.9	Marine Snow
	15	34.9	Fecal Pellets
	13	30.2	Molts
	14	32.6	Carcasses
17		39.5	Zooplankton/Nekton
	12	27.9	Cnidarians
	11	25.6	Ctenophores
	12	27.9	Polychaetes
	11	25.6	Mollusks
	13	30.2	Crustacea
	10	23.3	Echinoderms
	11	25.6	Chaetognaths
	11	25.6	Urochordates
16		37.2	Benthic Invertebrates
	12	27.9	Porifera
	12	27.9	Cnidarians
	12	27.9	Polychaetes
	12	27.9	Mollusks
	12	27.9	Crustacea
	9	20.9	Echinoderms
	9	20.9	Urochordates
14		32.6	Algae
	13	30.2	Phytoplankton
	12	27.9	Macroalgae (attached)
	12	27.9	Macroalgae (drifting)
17		39.5	Fishes
	12	27.9	Pelagic
	14	32.6	Benthic

In addition to completing the checklist, many PI's included invaluable comments and suggestions for the inclusion of additional variables. Recommendations related to the structure of the database form to be used for collection of the information was also made by several investigators. There was a decided split in the comments received. Some investigators suggested that as many variables as possible be included on the form, while others suggested that the form be kept simple. The two overriding concerns expressed by the PI's were: 1) to ensure that the form was completed by as many researchers prior to departing a research vessel, and 2) to create a format that would be flexible and as such address the needs of physical, geological, chemical, and biological oceanographers. The comments of this latter group were heeded in the design of the final database form. The form was kept short/and open-ended.

A version of the database information form as utilized on missions for 1989 appears below. It is straightforward, fairly short, and relies upon the scientist to describe the variables included in the study. A drawback of this format is that it requires that the data entry person be able to interpret the data/information collected and categorize it within the defined variable structure.

1. Research Project Number ______________________
2. Principal Investigator ________________________
3. Location ____________________________________

4. Date ______________
5. Dive Number ______________
6. Submersible Dive Number ______________
7. Observer Fore ______________
8. Observer Aft ______________
9. Sub Pilot ______________
10. TD 1 at Launch ______________
11. TD 2 at Launch ______________
12. Latitude at Launch ______________
13. Longitude at Launch ______________
14. Video Tape Number ______________
15. Time/length of dive ______________
16. Depth range of dive ______________
17. Bottom Water Temp. ______________
18. Bottom Water Visibility ______________
19. Water Conductivity ______________
19. Current Speed/Direction ______________
20. Transmissivity ______________
21. Dive Tasks/Samples ______________________________

20. Organisms/Substrate ______________________________

21. Comments ______________________________

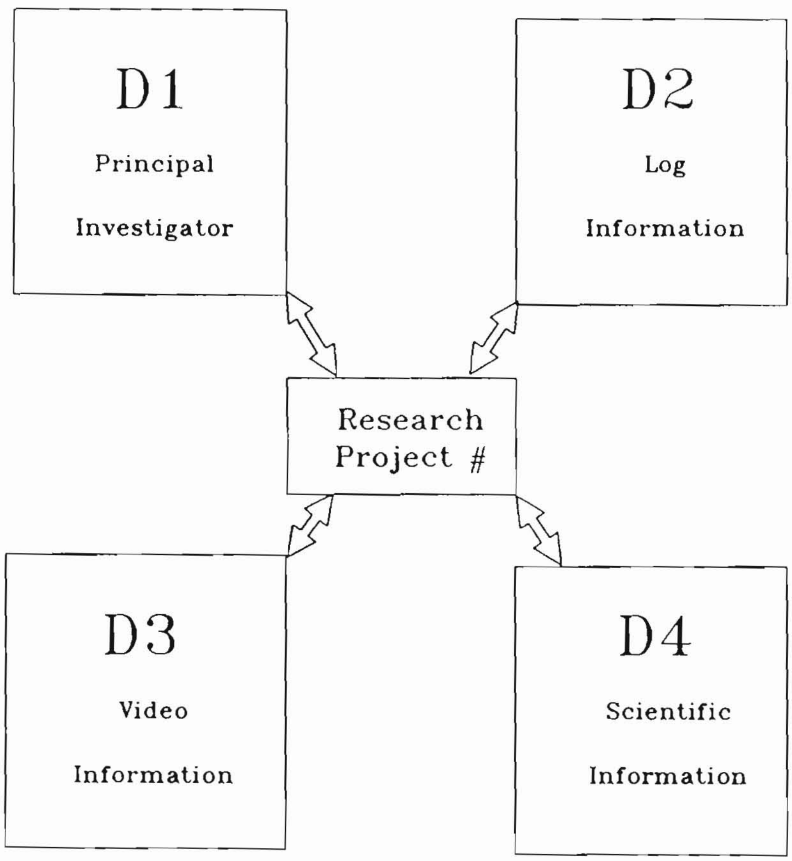
For 1989 this database collection form was completed by an onboard representative of the NURC-UCAP. In subsequent years a two part form will be used where much of the logistic information, i.e. location, dive number observer, video tape numbers etc. will be added by the NURC-UCAP representative, while the inclusion of the science categories will become the responsibility of the researchers.

Database Design

The data "entities" are the distinct pieces of information that will be entered into the database. In the case of underwater research, the information included in the above form represents the kind of data that are routinely collected on a research cruise. A DBMS must be able to allow the use of simple instructions to define those data that the scientist wants retrieved, processed, or outputed. A "query by example" system (Zloof, 1974) database system provides this capability, via the use of a suite of standard key words that can be utilized to complete the data query, retrieval, processing etc.

The "query by example" system combines naturally with the "relational database model" (Codd, 1970) to comprise a powerful, flexible DBMS. The relational data model is the mathematical theory of "relations" which is based on set theory, a branch of geometry describing relationships. The relational data model allows the user to perform the above operations (query, retrieve, store, etc.) through the "query by example" system without being at all concerned about the actual formats, order, indexing, or other particulars of the data stored within the databases. The aspect of set theory that applies to a relational model is that a particular entity or data set can be a subset of several larger sets. This subset, in effect, links the other sets together, usually by forming a common or nested hierarchy of all the entities in data subsets (Figure 5).

FIGURE FIVE
RELATIONAL DATABASE STRUCTURE



The diversity of data collected by NURC-UCAP sponsored scientists requires the design of a relational database model as opposed to a flat file format. A relational database is one composed of collection of sets (e.g. D_1, D_2,...D_N) within which the common element represents "primary key" that can be used to link the data sets (Figure 5). The value of such a system is that unique data entry formats can be accommodated within a set and that the data sets are kept at a more manageable size. This will minimize search and query times besides facilitating data quality control.

The primary key that was assigned to each of the missions was the Research Project Number (item # 1 on above form). This number is an alpha-numeric sequence that in itself imparts information. A example of a Research Project Number could be: "89-JSL-1-01". In this sequence the 89 refers to the year of the cruise, JSL is the abbreviation for the research platform (in this case the Johnson Sea Link submersible), the next number refers to where the research was conducted: Region (I, II, or III), the final number is the number of the research leg assigned to that particular mission. This number was then assigned to each of the individual dives that were made and recorded on the above form.

The database form addresses four distinct datasets that comprise the information collected and linked by the primary key. These datasets (D_1 - D_4,

Figure 5) represent the following basic categories of information or groups of information and references the numbers of the standard data collection form used in 1989 that is listed above.

D_1) - Principal Investigator Information - this relies only upon Form numbers 1 and 2: number 1 is the linkage key, while # 2 refers to the PI's name. The remainder of the information in this dataset is available outside of the form in the original proposal received from the PI and includes address, telephone information, and a list of pertinent publications that are associated with the research being conducted.

D_2) - Log Information - comprise basic ship/dive information which draws heavily from the form from numbers 3 - 6, and 10 - 13. This information allows for the generation of basic operational statistics for each of the three research regions supported by NURC-UCAP. In addition, it is this dataset that references the geographic coordinates of the dive location which eventually will be included in the GIS via the latitude/longitude and Loran - C coordinates. The dataset also provides the historical reference to areas that have received in situ support from NURC-UCAP in the past five years, and as such can act as a reference for future investigators wishing to conduct research in a given area.

D_3 - Video Information - draws only from items number 1 and 14 from the form, which is linkage key again, and a reference to the video tape number collected on the dive that is available in NURC-UCAP's archive. It is a point of NURC-UCAP science management philosophy to give the original tape (3/4" or 1/2" format) to the PI, and to patch an additional 8 mm videorecorder into the camera to provide NURC-UCAP with a duplicate tape in a small, high quality format. This duplicate provides an insurance to the investigator should a disaster (e.g. fire) destroy the datatapes, and also provides NURC-UCAP substantial raw stock video to use for summary video tapes that are useful for the other user groups (upper level management, policy makers, and the general public).

D_4 - Science Information - represented in this dataset is the linkage key (1) and scientific observations recorded in Form numbers 15 - 22 of the data collection form. The type of data collected provide basic science observations of each dive as well as any sampling or experimental tasks performed on a particular mission. For example, a series of box cores could have been taken that were subsequently analyzed for infaunal composition or sediment analyses of contaminant loads. Species information from this dataset and subsequent analysis of the videotapes will provide invaluable in situ groundtruth for the GIS systems (see Chapter Four).

A scenario illustrating how the relational database is made up of the four datasets (Figure 5) would be the following. If a scientist wished to conduct research in a given area he could use a keyword to query "location" and "research project number". The result of this query would be a table of all research projects undertaken within the desired location. The researcher could then use the linkage key (research project number) to search the other datasets to determine if and/or what videotapes were available in D_3 (Figure 5). These videotapes could be copied and sent to the researcher querying the database. Information about the PI who did the research and any publications generated from it could be searched from D_1. Information about the number and exact location of the dives is available from D_2 (Figure 5) etc. Finally, additional biological, geological, physical data and information about any sampling or experiments conducted in that particular area could be searched from D_4.

All of the information from the data forms and research proposals are currently being inputed into the NURC-UCAP database. This work is done by graduate students. Quality control is exercised by the author. It is envisioned that information/data allocated to D_1, D_2, and D_4 will be completed for by the end of 1989. The Video Information dataset D_3 will include a scan of all tapes dealing with species and substrate information, and is expected to be complete by the spring of 1990. When this first years data is entered and quality checked, reports will be generated for each of the PI's involved and an overview of the entire database sent to each along with all of the information collected from his/her mission.

Relational Database Software Selection

A prerequisite to data entry, however, was an informal assessment of the types of computer software available to handle the tasks of relational database management. Several criteria had to be met including 1) the ability to easily handle relational datasets, 2) the ability to convert the information in the datasets into ASCII (American Standard Code for Information Interchange) for export/upload into a Geographic Information System, 3) the ability to easily produce detailed reports of the information held within the datasets, 4) being user friendly, and 5) last, but not least the price (a ceiling of $600 was imposed due the University of Connecticut's allowable procurement procedures without involving a lengthy, competitive bid process). Several leading computer magazine's assessments of the relative strengths and weaknesses of the leading relational database software packages were used for product performance information. Prior experience with other database packages and software vendors was also considered in the choice. Leading data management software packages considered included: dBase III +, Foxbase +, Paradox 3, Q & A, and RBase III. Of these packages one that promised a good combination of features was Paradox 3, which also manufactured a spreadsheet program currently being utilized by NURC-UCAP.

The selection/recommendation using Paradox 3 was infuenced by the PI's product familiarity.

CHAPTER FOUR

DATABASE INTEGRATION INTO A MARINE GIS

GIS Overview

The NURC-UCAP database described in Chapter Three was designed for integration into a marine Geographic Information System (GIS). A GIS is "a computer-based methodology including hardware, software and graphics that encodes, analyses, and displays multiple data layers derived from various sources...in geographically coordinated, mapping format." (American Farmland Trust, 1985). Several key advantages of a GIS are inherent within this description. First, a GIS is a "computer-based" system, and as such has all of the advantages of rapid analysis, massive data storage and retrieval capabilities, and especially important flexibility. This last component is extremely important in mapping/cartographic applications that would be immensely time consuming if drawn by hand. The ability to encode (i.e. store), analyze (i.e. compare, projecting etc.), and display are key components to understanding natural resource location, utilization, conflicts, and their possible resolution.

The ability to store, manipulate and display "multiple data layers" is one of the cornerstones of a GIS. More than three or more data layers in hand-drawn maps become difficult to compare and understand, while a GIS has to integrate and compare many datasets simultaneously. The Bureau of Land Management (BLM) utilizes a GIS for analysis of the effect of mineral development on the environment that may include over a hundred data layers (Allen, 1986). In addition, analyses of these layers and how they interact with one another can be made when appropriate algorithms have been established for these associations. For example, rainfall levels over various soil maps can be displayed, and when combined with erosion rates of the various soil types and slope data can be applied to the Universal Soil Equation to yield valuable information about soil loss within a given area. The other cornerstone of GIS is the fact that they utilize a "geographically coordinated, mapping format". This means that all of the information in a GIS is spatial data - geographically registered to some standard Cartesian grid location. The advantages of this capability, when combined with a Database Management System (DBMS) are significant.

> "Relational tabular data bases linked with topologically structured cartographic data bases better reflect the "world itself," rather than replicate the inflexible structure of map representations" (Baumann et al., 1986).

The method of geographic registry varies, depending upon the means of data collection and input, but can include standard USGS quadrangle maps, other map projections, and remote sensed data based on the Universal TransMercator (UTM) format, or on the Global Positioning Systems (GPS) to record geographic coordinates. The combination of computer based analytical power, with spatially coordinated data makes the issue of scale moot, as most

GIS systems can expand or condense spatially displayed data at will, while at the same time maintaining spatial integrity.

GIS Hardware

In terms of hardware, a GIS is comprised of a computer, most systems have been housed on mainframes, but with the proliferation of the 80386, 32 bit CPU in microcomputers, these machines when equipped with a 80387 math co-processor are capable of performing the complex, computational tasks required of a GIS. In addition to the CPU, a GIS should have a digitizer, usually a large tablet that reads X and Y coordinates from electromagnetic points imbedded in its surface. In this way direction and scale are maintained when maps are overlain and digitized. Maps utilized for tracing are ideally made of Mylar, which is impervious to water content changes that affect the true size of traditional paper maps. The third component of a GIS is a high resolution multipalette graphics display screen that has the capability to depict multiple overlays representing the various datasets. Another GIS hardware requirement is a data storage capacity commonly in the form of large hard discs (internal or external e.g. Bernoulli Boxes) or mass tape (tape loop cartridges or 9" standard) storage disks. The final pieces of GIS hardware for a GIS are a high quality printer for output of tabular data and a large, multi-color plotter for production of high quality mapped information.

GIS Software

Most popular GIS systems have developed a two-tiered structure to deal with the two main components of the system, one to manage the data in tabular or written format, and the other part dealing with the geographic registry, display, and production of hardcopy maps. The first component of a GIS is the true database of the system and the portion that would provide the interface for much of the data collected in the NURC-UCAP database. The second component is the means to display the spatial distribution of data available from the database. The specific software required to conduct these two processes are an integrated series of programs such as 1) methods to link attribute information to specific areas which this data describes and 2) utility programs designed to manipulate lines, points and arcs used in the drawing of maps, (Monmonier, 1982).

ARC/INFO

In the New England region an increasing number of states and local agencies are adopting a particular GIS, called ARC/INFO. Environmental Systems Research Institute (ESRI), a consulting firm, was hired to evaluate the needs and define the software and hardware for the Illinois Natural History Survey. This organization developed ARC for processing the geographic information and interlaced this with INFO, an commercial database management system (Brookfield, 1986). ARC/INFO utilizes a "tool box" approach with various sub-programs available for specific tasks, such as "digitize", "editplot" etc. ARC/INFO assigns each point, line or polygon a number, which in turn can be given a code by the operator. These codes become the linkage of the cartographic files to the database (entity) files that hold information about a mapped file. The entities can be grouped together by code, linked to files containing assigned colors, patterns or fonts, and subsequently displayed in the correct spatial context. This assignment of codes to the entities in a geographic context allows for combination and/or intersection of various pieces of information about a given area. For example, a polygon area can be linked to soil type and tree cover files for analysis of species to soil type association. Changes of scale within ARC/INFO are also possible, but limited by the resolution of the original digitized image, for when the scale is reduced detail is lost because the distance between digitized points is increased, for example, digitizing a state map with county boundaries and then displaying an individual county would produce a sketchy map of that county (Brookfield, 1986).

The procedure for development of ARC/INFO files is the same as any GIS, a base map is digitized as starting point for input of all other information. The base map for a state system usually is a geopolitically bounded map such as USGS quadrangle (covers an area of seven and one half minutes of latitude and longitude). Then overlay maps of specific features - natural (e.g river systems, lakes, bedrock type, land cover etc.) or anthropogenic (town boundaries, roads, population etc.) are digitized into the base map. These overlay maps are aligned to the base map by at least four standardized points called tic marks (ESRI, 1984). This frame of reference is necessary to accurately display the overlay maps, particularly when multiple overlays are displayed.

GIS store various inputs in a common coordinate system at a common resolution. Two commonly used data structures are the "raster" (or "grid") and the "polygon" formats. Raster formats require that each data element be assigned a constant value over a rectangular region, all such regions having the same dimensions. Polygon format assigns a constant value over a polygon instead, where the "polygons" arise from the actual boundaries between the various information or mapping units (Ramapriyan et al. 1981). As a polygon-based format, ARC/INFO stores information within polygons that are digitized from the tablet into the computer. As such no two polygons are likely to have the same size or shape.

There are distinct advantages of either format. A raster system offers the potential for direct input of remotely sensed, and classified data, allowing for enhanced analytical capability, but requiring large amounts of disk storage space and limited output facility (Allen, 1986). A polygon format is more efficient in terms of storage, since the size of a piece of information stored can be reduced to one unit as opposed to an aggregate of many similarly classed rectangles. The mapping/output capability of these systems is also greater

(Allen, 1986). In addition, ARC/INFO as a polygon format, has been chosen as the system of choice for many state-level resource management agencies. All of these points combine to make ARC/INFO the system of choice for many terrestrial applications and the attractive alternative for marine-based applications.

GIS Applications

GIS technology has been available for the past 20 years, with the earliest attempts being initiated by the Department of the Interior (DOI) and allied with NASA in 1977 to focus on a digital image inventory of vegetation types (Allen, 1986). In 1982 the DOI formed the Interior Digital Cartography Coordinating Committee (IDCCC) to determine the data categories for a National Digital Cartographic Data Base (Kleckner, 1986). The IDCCC also was tasked with coordination of inter/intra departmental data exchanges. Additional DOI uses of GIS include the Land Use and Land Cover Mapping Program, the National Coal Resources Data System, the National Uranium Resources Evaluation Program, the Rock Analysis System, and the National Water Data System (Nystrom et al. 1985).

Governmental mandates on a state level have often acted as catalysts for the development of GIS. A typical example is the Federal Surface Mining Act of 1977 that stated that if a state failed to conform to certain federal standards and recommended processes, the Office of Surface Mining would initiate its own surface mining program (Antenucci, 1981). Potentially affected states of this one Federal Act included Kentucky, West Virginia, Pennsylvania, Nevada, Colorado, Montana, Idaho, Wyoming, Utah etc. Hence, the institution of state-level GIS is nearly universal.

Several other major forces are involved with the evolution of GIS applications. One of the most rapid is the evolution of the technology itself. Smaller, more powerful/portable computers have extended GIS to the field level data collection (Youngmann, 1981). The integration of remotely sensed data and modern optical scanning technology herald rapid data input, a typically limiting factor in GIS development (Dangermond, 1981). The need to understand and manage natural systems, especially those involved with renewable and nonrenewable resources and environmental impact assessment will continue to accelerate GIS development.

GIS Applications in the New England Region

To date, almost all applications of GIS technology have been terrestrially based, and as is true with much modern technology was developed first for use in industry, particularly land resource management for the timber industry (e.g. Yale School of Forestry and Environmental Studies, Maine Spruce Budworm Control program). Natural resource managers and landuse planners were quick to recognize the merits of these computer systems, and as the hardware and software developed and became more accessible the level of

GIS utilization has grown. Owing to the still substantial level of monetary and manpower resources required to implement a GIS, they have largely developed on a state/regional level. Within New England, the agencies responsible for natural resource and environmental management have led the way in GIS implementation, e.g. Rhode Island's Department of Environmental Management, Connecticut's Department of Environmental Protection, Maine Department of Conservation etc. A new requirement for states to manage their own low-level nuclear waste is also drawing heavily upon the spatial/analytical capability of GIS in facilitating siting decisions for storage of this long-lived toxic material.

The Connecticut Department of Environmental Protection's Natural Resource Center and the U.S. Geological Survey is a typical regional implementation of GIS. The project began on a small geographic scale, encompassing two 7.5 minute quadrangles in north-central Connecticut (Nystrom et al., 1985). The applications of this system were: 1) the development of an industrial site selection model, 2) determination of groundwater availability for water utility development, 3) data base generation for 3-D groundwater model, and 4) 7-day/10-year low flow model (Nystrom et. al. 1985). This project is continues today with almost state-wide coverage (Prisloe, personal communication).

Coastal and Marine Applications of GIS in the New England Region

The utilization of GIS's for resource management in the coastal zone is a natural application of this technology and is rapidly increasing in New England and in the Canadian Maritime Provinces. More specifically, its utilization as a tool for the Gulf of Maine was addressed at a recent conference convened by the governors of the states of Maine, New Hampshire, and Massachusetts, and the premiers of New Brunswick and Nova Scotia. The conference was called: "The Gulf of Maine: Sustaining Our Common Heritage" and was held in Portland, ME. This conference was an extension of the Gulf of Maine Initiative which seeks to "increase understanding of the Gulf's resources and to develop action recommendations that can be implemented by the states and provinces." The three major activities of this initiative have been to develop an environmental monitoring plan, produce a Gulf of Maine ecosystem report, and to convene the above mentioned conference which resulted in the signing of a formal agreement among states and provinces recognizing the Gulf of Maine as a common resource shared among the states and provinces and to cooperate in its wise management.

A separate session was held on prior to the conference entitled: "Geographic Information Systems in the Marine Environment: Applications for Policy Makers and Managers" wherein representatives of the three states and two provinces described the status of marine GIS (MGIS) implementation in their respective areas. The following synopses are provided to illustrate the state-of-the-art in the region as presented at the conference.

MAINE

A Maine state GIS system for terrestrial applications is currently being implemented by the Department of Conservation utilizing the ARC/INFO package described previously. This system is running on Sun Microsystems hardware. The state has yet to formally initiate any marine-related projects, although several agencies have recognized the potential of the technology; including the Department of Marine Resources (DMR) which plans to have two GIS workstations connected to the Department of Conservation's system. The DMR has a critical need to map areas closed to shellfish harvesting, a task currently done by hand. GIS - produced maps could be prepared and distributed to the shellfishermen covering areas where public health is at risk. The Department of Environmental Protection, with responsibility to monitor discharges into coastal waters could also utilize the system to map discharge locations and perhaps to model outflow distribution patterns. The University of Maine and the Maine Geologic Survey are also presently instituting ARC/INFO for use in the marine environment, which will be described in greater detail below in connection with NURC-UCAP's database.

NEW HAMPSHIRE

The Office of State Planning established ARC/INFO on a Prime computer system in 1984. This was done in response to a proposed repository for high level nuclear waste in New Hampshire. Several PC-based versions of ARC/INFO are being utilized by other agencies including the Department of Environmental Services for water resource management. A few applications have focused on coastal and estuarine waters such as bathymetric contour modeling of Great Bay, wetlands mapping in conjunction with the evaluation of siting criteria for hazardous waste facilities. No true marine applications are currently planned as a part of the New Hampshire GIS program.

NEW BRUNSWICK

The Canadian province of New Brunswick has applied GIS for land-based uses for many years. A collaborative effort of private industry, academia and the public sector produced CARIS (Computer Aided Resource Information System), a GIS software package (Chandra et al., 1989). In 1989 the premier of the province established the Geographic Information Corporation (NB GIC), a Crown Corporation with responsibility for all of the government's basic geographic information activities (Chandra op. cit.). A task force was formed in 1989 by the Geographic Information Management Advisory Committee to develop a set of standards for the digital production of a series of coastal maps. The task force concluded that: 1) an inventory of data availability is needed for the coastal area, 2) the data required to produce a consistent series of coastal base maps is not currently available, and 3) the needs of the province in content and accuracies vary such that there is a need for multi-scale base data in the coastal area (Chandra op. cit.). No true marine based applications are currently being developed in the province.

NOVA SCOTIA

Nova Scotia is a peninsula bounded by four major bodies of water: the Atlantic Ocean, the Bay of Fundy, the Northumberland Strait, and the Gulf of St Lawrence. As such, the marine environment is of critical importance to the economic, environmental, and social welfare of the province. Within the province itself, a program for Coastal Zone Base Mapping has been established by the Provincial Land Information Committee. The major objective of this project is to serve as a geographic foundation on which to build the major provincial digital thematic mapping layers that require a truly hybrid marine and land-base map system.

More significant than this provincial coastal effort, however, is the St. Mary's University, Dalhousie University, and Land Registration and Information Service (LRIS) initiative to provide a resource and environmental digital database for the Gulf of Maine marine region including the Bay of Fundy and Georges Bank. The FMG (Fundy, Maine, Georges) project "seeks to create interfaces between a wide selection of databases which will enable data to be displayed on an electronic base map for many areas and themes incorporated into the system" (Ricketts, et al., 1989). The FMG project is rapidly developing as a true marine GIS, drawing upon the databases of both Canadian and U. S. agencies (Figure 6).

The information in the FMG project is being mapped at a scale of 1:2 million. The maps and text data will include information on physical, ecological and socio-economic characteristics of the region including bathymetry, bedrock and surficial geology, bottom sediments, physical and chemical oceanography, fish species distributions, political and administrative boundaries, population and land-use characteristics (see Appendix D). In addition, critical resource and environmental management issues will be included such as coastal and marine pollution, ocean

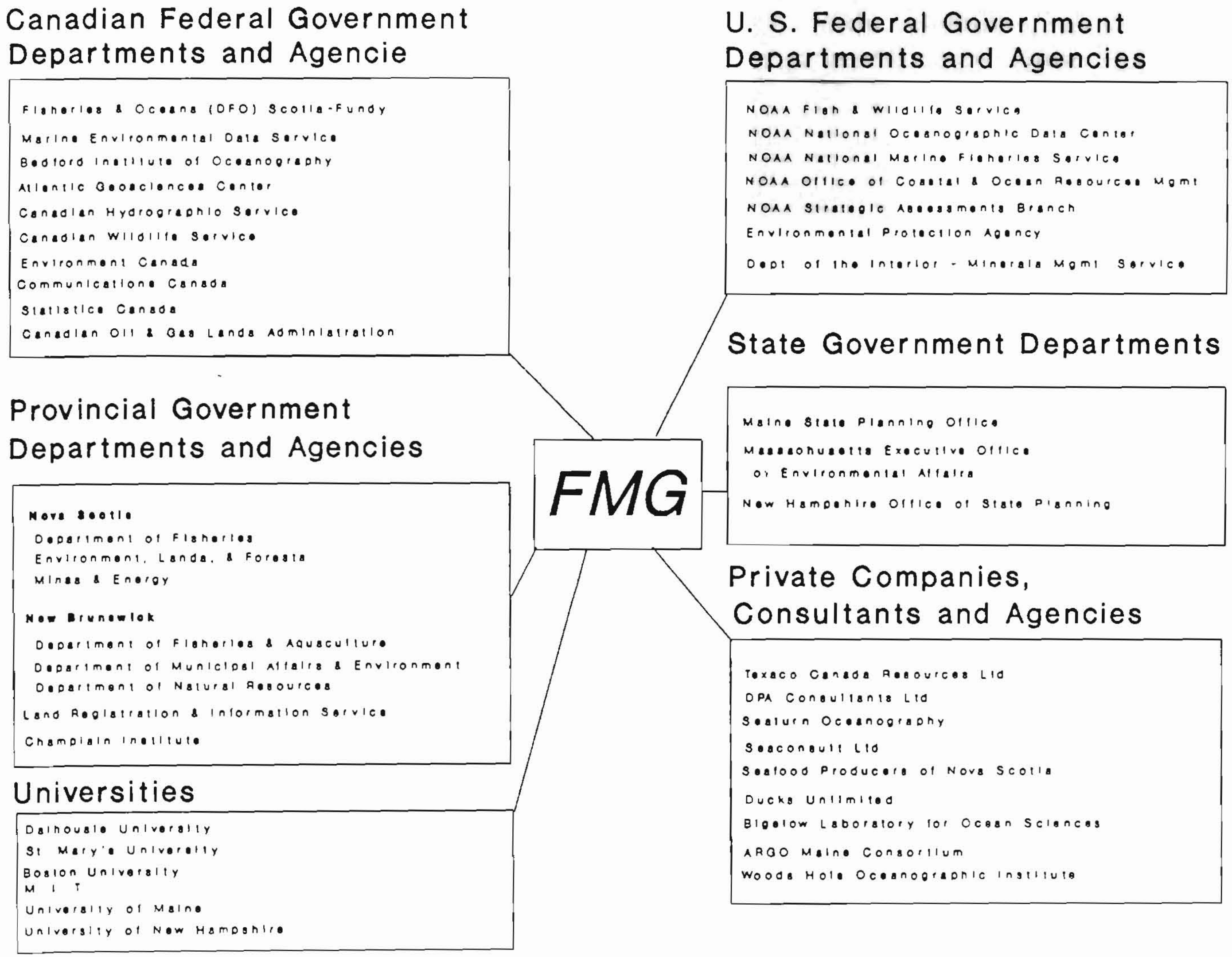
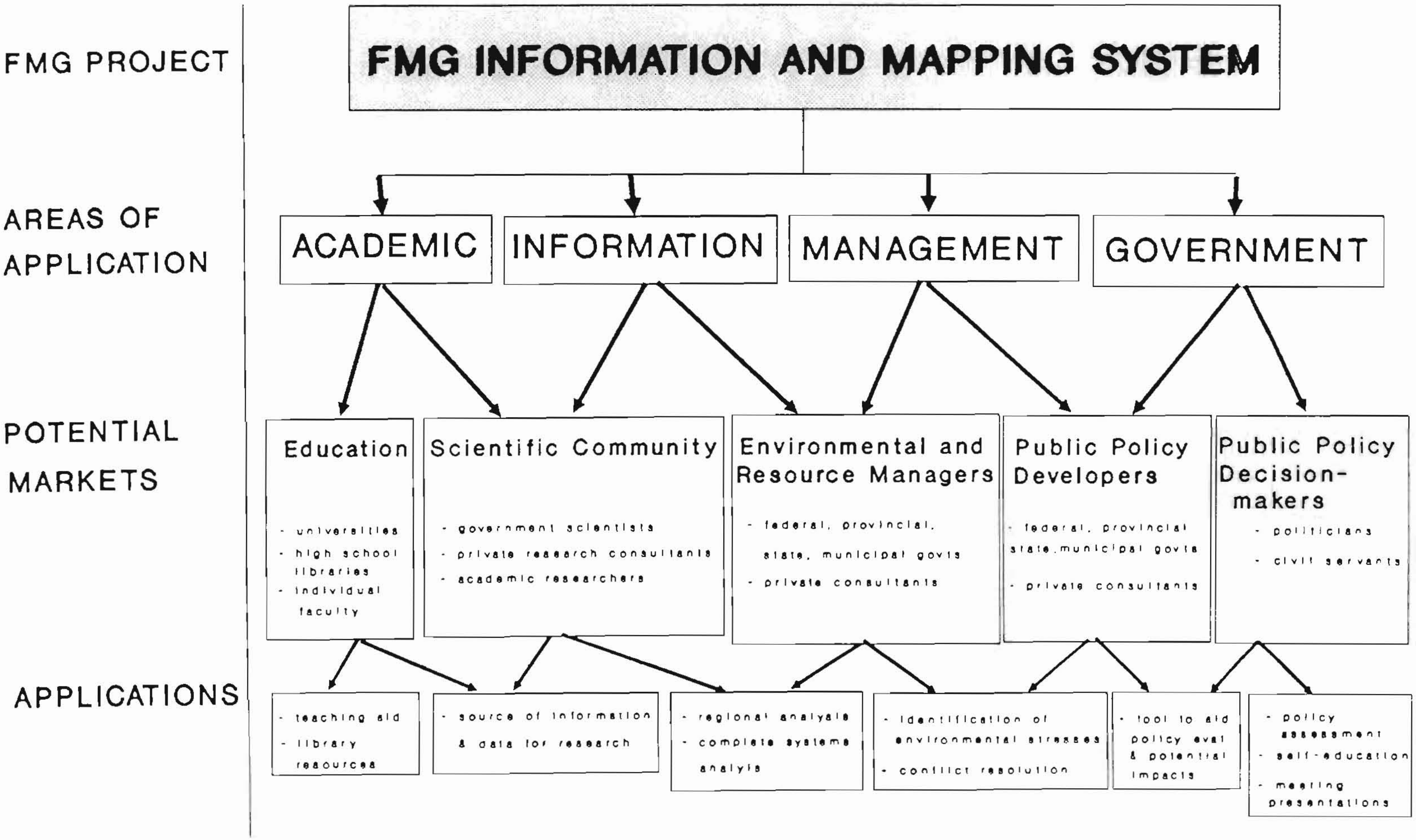


FIGURE 6
FMG SOURCE DATABASES

dumping, acid rain and aquaculture development. In the GIS, each map will be supplemented by data held within tabular format such as the parameters from which the map was derived, additional data and detailed bibliographic citation of the source of the information. The FMG project is currently based upon the CARIS software package and housed on a mini-VAX computer. A scaled down PC-based version is planned for the future, called Geomate. Geomate, while not being a total GIS, will provide users with access to the FMG database, allow for the display of maps, provide map overlay capability, and data searches (Ricketts, 1989). A strong attribute of Geomate is its ability to interface with other software packages including ARC/INFO and traditional database packages (dBase III). This latter component is extremely important if linkages (see below) between the Canadian and U. S. systems (most of which have adopted the ARC/INFO as a standard) are to result.

The FMG project is slated to be completed in early 1990 and intended for a diverse set of users (see Figure 7). The principal target applications are for resource managers, environmental agencies, and scientists. Educational and public outreach components are also envisioned (Ricketts, 1989).

FIGURE 7
FMG USER GROUPS



Depiction of Ocean Data in Three Dimensions

The data collected from the third dimension, the water column itself, remains a challenge for both programmers and data managers. However, rapid improvements in digital image processing in the science of meteorology may provide an analog for use in the water column. New image processing hardware and display techniques are being used to model the atmosphere to "fly through" an image of a block of the atmosphere and examine the structure and content of the meteorological parameters at any point within that block (Vonder Haar et al., 1988). This capability is generated by the combination of remotely sensed data from radar (Doppler) and satellites (GOES) with available surface data into display systems such as IRIS, McIDAS and SDHS. The result is a striking 3-D image of cloud topography that can be overlayed onto a 4.27 x 4.27 degree area that is mapped in a Mercator projection. By displaying the cloud topography in succession using an image processing system, cloud cover and cloud features can easily be associated with effects from underlying topographic features. The software provides the analyst the ability to choose the vertical scale of both the surface topography and for the cloud "topography".

The applications of this display technology in the field of meteorology have been for 1) pilot briefing, 2) forecaster uses, and 3) research and teaching (Vonder Haar et al., 1988). These capabilities can be expanded to include studies over periods of time that in effect are 4 dimensional studies. By such time sequencing of the combined images the development and dissipation of storms or less severe, yet significant convective activity can be displayed. In addition, these images can be rotated and viewed from various angles to further provide clues to their origin and fate.

The potential utility of these systems in the marine environment is obvious. The power to "fly through" the water column would be a natural depiction of the type of in situ data collected by NURC-UCAP and be applicable to almost all of the research themes supported. For example, movements of schools of fish might be modeled in relation to thermal boundaries, the dissipation and dynamics of sewage sludge plumes could be traced to accurately determine their fate. The data collection capability of manned and unmanned submersibles in the three dimensional space of the water column could be combined with traditional oceanographic techniques (bathythermographs, CTD devices, towed nets) and remotely sensed data (e.g. coastal zone color scanner, AVHRR) to provide the information similar to that used in the field of meteorology. Another exciting tool being utilized to trace the movement of zooplankton in the water column is dual beam sonar (Youngbluth et al. 1989) which is being used to locate and depict the three dimensional patches of these organisms. This information, when stored in digital format has the potential of being manipulated and displayed with similar devices used in atmospheric stereo and false-stereo systems (Hasler et al., 1985).

More simplistic three dimensional images are being explored by Connecticut's Department of Environmental Protection (Lewis, personal communication). This imaging will involve the cross-sectional digitization of sub-bottom profiles taken of Long Island Sound (LIS) again using ARC/INFO. These profiles will then be analyzed to provide quantitative information about water depth, sediment, and bedrock thickness. The profiles were originally taken along shipboard transects made in LIS. These hard copy tracings will then be depicted on a three-dimensional X-Y-Z coordinate system utilizing the capabilities of the ARC/INFO GIS. The various profile segments (water depth, sediment thickness etc.) will be depicted as quantitative informational layers. This application of the analytical capability of the ARC/INFO system will allow for the analysis of the rate of sediment accumulation or erosion from one year to the next as additional studies are made.

Much of the information collected in Data Set D_4 (Scientific Information) could also be mapped in three dimensions on a GIS system. In addition to the discrete data points collected during the dive, other basic oceanographic data is recorded on each dive such as conductivity, temperature and depth. This information is downloaded onto high density 5 1/4" floppy disks and maintained at NURC-UCAP. The potential for development of three dimensional models within the GIS by assigning discrete depth strata to GIS files and displaying these is a viable future option, however the small areal coverage of a sequence of NURC-sponsored dives makes this modeling effort of limited utility, only serving the interests of the scientist conducting the research. Nevertheless, the development of techniques to present ocean data in three dimensions represents an exciting future expansion of GIS.

CHAPTER FIVE

NURC-UCAP PILOT GIS PROGRAMS

NURC-UCAP has recognized the potential of the GIS as a tool to assist in its management of underwater data. The nature of data collected using in situ techniques is often site-specific and associated with specific geographic locators (i.e. latitude and longitude or Loran-C coordinates). As such this data can be digitized and mapped using a GIS and the ancillary data collected can be maintained in a complementary database. The linkage of the database information with the GIS is an area that has been recognized as one needing improved efficiency (Baumann et al., 1986). The limitations of the linkage have been identified as the lack of a powerful, user friendly database software. A dedicated "query by example" database software package (i.e. Paradox) is being used by NURC-UCAP to overcome the limitations of the INFO portion of the ARC/INFO package. A future version of this GIS software, ARC/DBASE is soon to be released (Prisloe, personal communication) which will allow use of the DBASE package by NURC-UCAP in the future.

NURC-UCAP has begun to explore the feasibility of linking its database with the power of a GIS in two pilot programs. These endeavors have been of a modest scale to date in order to function as proof-of-concept studies. The two projects are presently being implemented and the following descriptions are status reports.

University of Maine

In 1988, Dr. Joseph Kelley and Dr. Daniel Belknap, Geology Department, University of Maine and the author submitted a proposal to NURC-UCAP for seed money to begin implementation of a GIS system to manage data collected using manned submersibles in the Gulf of Maine. The proposal was for the purchase of digital bathymetric data from NOAA's National Geophysical Data Center (NGDC) to serve as the base map for a GIS system to be established at the University of Maine (see Appendix E).

The objective of the proposal was to overlay this base map data with information collected on manned submersible dives relating geological information (e.g. substrate type, sand wave dimension, bottom topography and slope) and biological information (species abundance and distribution). The proposed project was to serve as a pilot study to determine the course of development of a larger GIS to cover the entire Gulf of Maine. The proposed project area was located off the coast of Maine extending from Small Point and Seguin Island in a west-east direction, and from Popham Beach south, approximately 11 kilometers (Figure 8). Within this area numerous submersible dives, bottom samples, side scan sonar images, and seismic reflection profiles have been taken that provide the beginnings of the ancillary data (Figure 9).

FIGURE 8
LOCATION OF MAINE PILOT STUDY

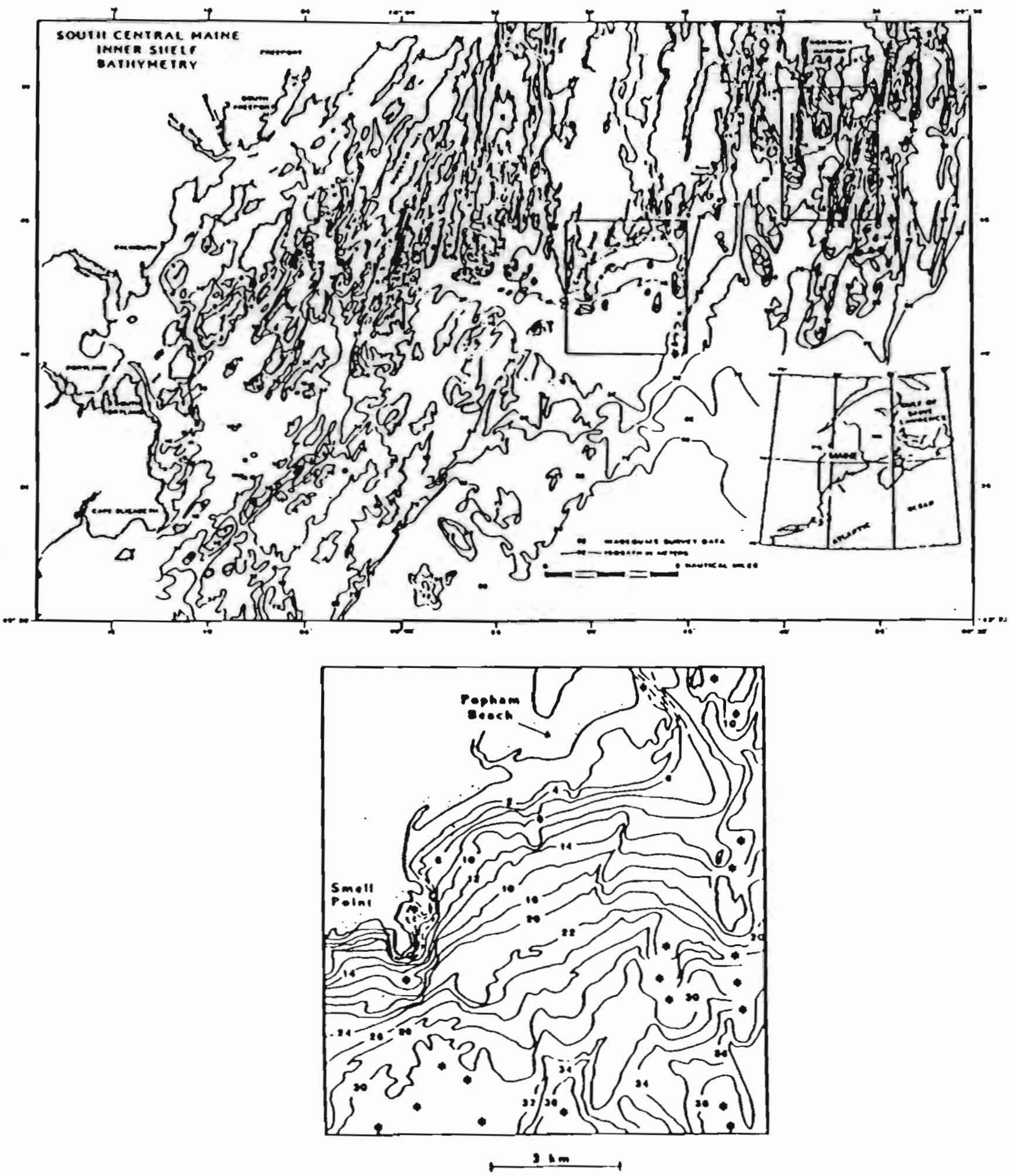
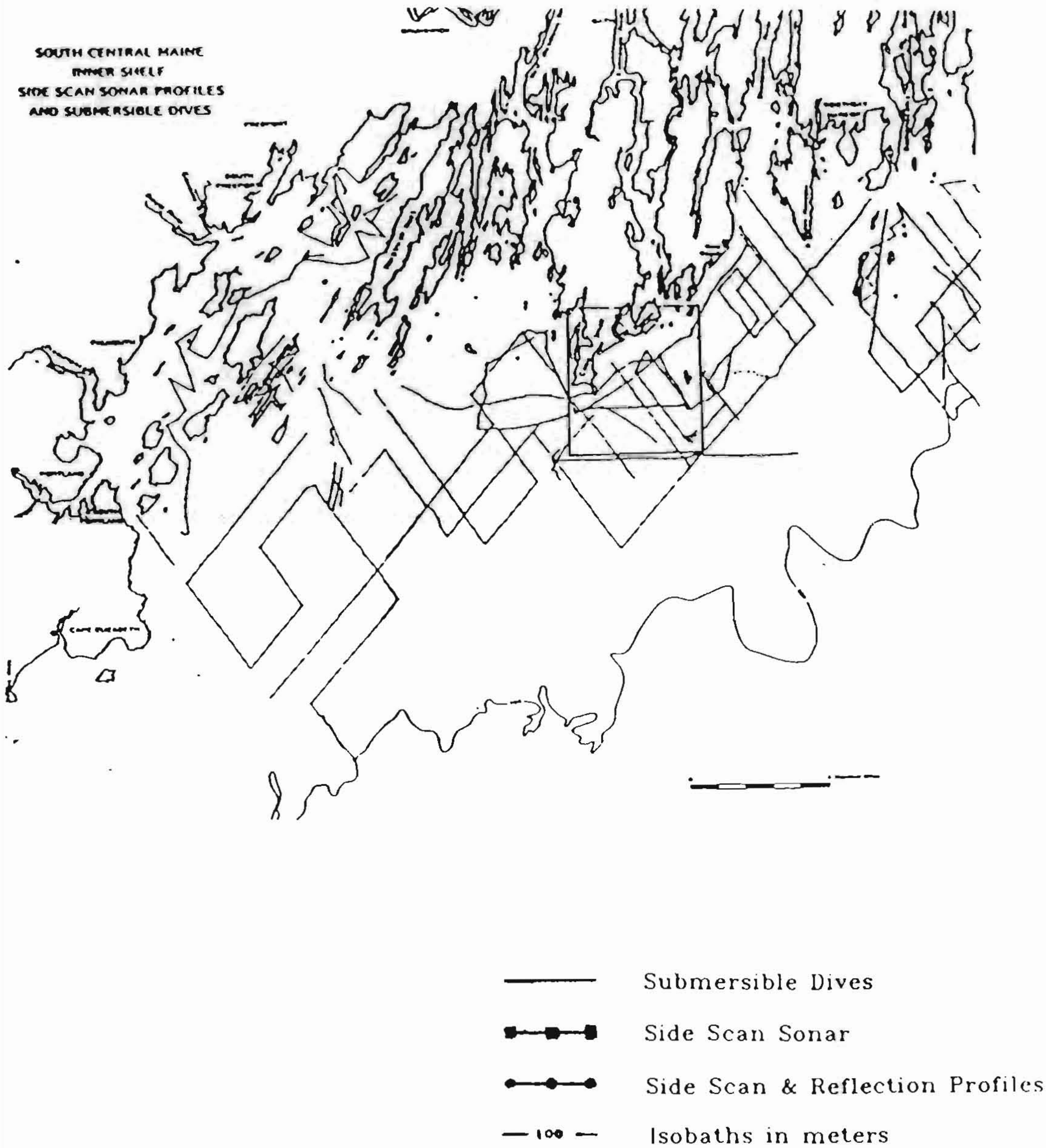


FIGURE 9
DIVE SITES IN MAINE PILOT STUDY



The GIS to be implemented at the University of Maine is the PC version of ARC/INFO. Using the GIS, menus will be developed to integrate the information collected and stored in the NURC-UCAP database. The initial proposal, submitted prior to completion of the NURC-UCAP Principal Investigator survey included the following variables (Kreiton, 1989):

- Bathymetry
- NURC-UCAP Dive Information
- Depth Range
  - Substrate Information
  - Organisms observed on dive
  - Video coverage/information
  - Other (as requested by NURC-UCAP)
- Bottom Samples
  - Points
  - Grain Size (parameters)
  - Percent $CaCO_3$
  - Percent C
- Side Scan Sonar Tracings
  - Line 1
  - Line 2
  - Line 3 (etc.)
- Seismic Reflection

The original proposal's budget requested funds for the rental of the hardware and salary for Ms. Kreiton who was to serve as the initial data entry person. An estimated a three month time frame was projected to implement the system. The final result was to be functional GIS for the project area, listing all available data, and utilizing Loran - C coordinates, latitude and longitude, or state plane coordinates to georeference the data. Funding delays from NOAA in early 1989 prevented the emplacement of funds to complete this project within the proposed time frame. Instead, funding for this project was utilized for the purchase of the digital bathymetry and for the employ of another data entry person. By 1989, support for the GIS concept for marine information had grown to the point that the University of Maine's Center for Marine Studies purchased the GIS hardware and software. This system has recently (November, 1989) come on line, following solution of several hardware acquisition delays.

Within the next few months all of the available data within the original pilot area will be entered and the production of hard copy maps will begin. The available data from all NURC-UCAP supported investigators who have conducted in situ projects within this area is being formatted for inclusion into the NURC-UCAP relational database described in Chapter Three. In this manner, the linkage between these two databases can be firmly established by relying on the simplified data entry and manipulation of the Paradox DBMS, while maintaining the power of the ARC/INFO system for data display and analysis. It is hoped that hands-on demonstrations and dissemination of high quality, informative hard copy maps of the Gulf of Maine will demonstrate the utility and flexibility of the system. In this way it is hoped that investigators will voluntarily provide data collected using in situ technology in the Gulf of Maine in order to make the GIS as complete and functional as possible. The standardization presented by the ARC/INFO and ASCII formats also will facilitate the coordination of the efforts of the University of Maine and

NURC-UCAP with Nova Scotia's FMG project previously described via the Geomate software package to develop a truly complete Gulf of Maine GIS.

Long Island Sound/Connecticut Department of Environmental Protection Cooperative Program.

For 1990, NURC-UCAP is in the process of developing a cooperative research program with Connecticut's Department of Environmental Protection. The program will address some of the most pressing regional research needs of Long Island Sound (LIS). LIS is an extremely valuable resource for the states of Connecticut and New York providing recreational, natural resource and transportation resources. LIS is presently severely impacted by nutrient loading and contaminant inputs from the heavily populated and industrialized south coast of Connecticut and northern coast of Long Island. The nutrient loading is produced from sewage treatment plants that don't have the capacity to handle the normal input especially during heavy storm drain input. These events, combined with warm summer temperatures and concomitant water column stratification have produced incidents of hypoxia in LIS, whose impacts have been manifest in fish kills and toxic algal blooms (CT DEP, Annual Report, 1988 . LIS has been the target of a protracted joint NOAA/U.S. EPA funded project (Long Island Sound Study, LISS). The LISS has, however focused solely upon the hypoxia problem, largely through modeling efforts. The impact of these events on the benthic living resources of the sound is unknown (B. Welsh, personal communication). In addition, current measures

of the levels of heavy metal and organic contaminants in the sediments and tissues of commercially and ecologically important species are also deficient.

To this end, the proposed cooperative program between Connecticut DEP and NURC-UCAP represents a natural union of resources. Three major research themes have been identified that can best utilize the "state of the art" in situ technology available through NURC-UCAP to begin to address the problems evident in LIS. All three major research themes of this cooperative program will be linked by a GIS system that is presently up and running at the University of Connecticut's Avery Point campus (home of the NURC). The following describe the major research themes of the proposed NURC-UCAP/DEP project.

1). Habitat mapping

A complete knowledge the nature and extent of the living and nonliving resources of LIS is lacking. Therefore a cooperative program utilizing side scan sonar to conduct synoptic mapping of the substrate of LIS combined with subsequent in situ groundtruthing of the side scan images with a remote operated vehicle (ROV), will provide baseline information on: 1) habitat type, 2) animal/plant communities, 3) spawning-nursery-adult habitats, 4) identification of critical habitats, and 5) subsequent analyses of contaminant loads of sediments and key indicator species collected will provide a measure of the status and relative health of the sound. The project will identify potential "sinks" for nutrients and pollutants and the extent of commercially exploitable non-living resources (sand and gravel). In addition, the habitat mapping will provide a comprehensive inventory of Long Island Sound's physical and biological characteristics, focusing on the ocean floor environment.

This first research theme will rely most heavily on the power of the ARC/INFO GIS. The research methodology utilized to collect the data will entail the simultaneous use of side scan sonar and a Global Positioning System (GPS, e.g. Pathfinder) to precisely record the area surveyed. Immediately after the side scan is made, a ROV will be deployed to visually groundtruth the nature of the substrate and document the species abundance and distribution of this track. In addition, the small manipulator on the ROV will be used to take punch cores of the bottom sediments for grain size and contaminant analyses. The use of a tracking system comprised of acoustic transponders located on the ROV, combined with the GPS information will guarantee that the images recorded be the ROV's video camera exactly match the side scan sonar tracings. The GPS has the ability to download the geographic coordinates of the side scan/video/sample information directly into ARC/INFO, thereby eliminating the time consuming, error producing process of hand digitization.

2.) Long term monitoring

Since 1988, NURC-UCAP has been developing the framework for a long term monitoring program of ocean floor habitats and their associated biota. This framework consists of "superstations", specific sites that provide long term collection of a consistent suite of environmental and living resource parameters. The suite of measurements will include heavy metal, organic, nutrient and bacterial analyses. Superstations will also serve as geographic foci for peer-reviewed multidisciplinary research projects. These projects are generally process oriented studies to understand the biogeochemical events governing productivity and man's impact on the environment. How this monitoring program should be applied to Long Island Sound and the identification of superstations are major goals of the DEP/NURC-UCAP cooperative program.

The ability of a GIS to precisely record geographic points in combination with a plethora of information about these points makes it the most powerful means to manage information recorded at a superstation. For example, the locations of each superstation will be recorded on the base map of LIS collected as a part of the Habitat Mapping program, then all of the additional information collected/measured will be incorporated initially into the NURC-UCAP database and subsequently into the ARC/INFO system. The relational format of this database will greatly facilitate management of the variety and complexity of data collected at a superstation. Inherent in the definition of the concept of a superstation is its multi-temporal scale factor. This facet will also be accommodated by the relational DBMS and GIS by providing overlay maps that indicate temporal changes in the variables measured on annual/biannual/decadal time scales. This ability is critical for trend analyses and to facilitate modeling of changes in species distribution/abundance and man's impact on LIS.

3.) Public outreach and education

NURC-UCAP in 1987 embarked upon a very successful educational program called the High School Aquanaut Program (HSAP). Through the HSAP, students have the opportunity to experience the beauty of the ocean floor and its inhabitants, to become directly involved with the "scientific process" through their own research proposals or NURC-UCAP sponsored scientists' work, and to be exposed to the state-of-the-art technology required to conduct deep sea research. This program is a very successful means to educate today's youth, and through media coverage to expose a large segment of the population to the type of work being conducted through NURC-UCAP.

An expansion of the HSAP is proposed for Long Island Sound in conjunction with DEP/NURC-UCAP cooperative program. This extension is natural for it will provide more Connecticut high school students the opportunity to experience the nature of Long Island Sound through the first objective of habitat mapping. Direct student involvement on the side scan sonar/ROV cruises is envisioned, through a hands-on approach presently planned as utilization of an additional small ROV to allow further collection of video data for student use. These students will use the video data as centerpieces of presentations to be given to their schools, junior high schools and community organizations.

A final means for public education and outreach through the DEP/NURC-UCAP cooperative program and the HSAP is also planned. This component will involve the establishment of an educational resource center that will draw upon the power of the GIS to provide the general public with vivid graphical presentations of LIS and all of the environmental/habitat information contained in the database. Another exciting means to link the GIS system to the video documentation collected by the high school students is through and interactive video system, based upon a large map of LIS. This map would be overlain with a touch screen and the points where dives had been made would be represented on the map. In this way anyone could approach the information center, push a point on map and reference a video, taken by a high school researcher of that part of LIS. In addition, the interactive video system (e.g. Sony's View system) has an integrated "authoring" program (programmed in "C" computer language) that allows for the generation of menus that could access the data held in the ARC/INFO system. For example a menu system could welcome a viewer to the educational center, provide them a list of options of available tabular data held within the database, perhaps the fishing yields of LIS, or heavy metal contaminant levels associated with a point on the touch screen map. In this way comparison of the ecological and environmental status of LIS is vividly presented to the general public and spatial comparisons between different locations can be made.

CHAPTER SIX

SUMMARY

As a subdivision of the National Oceanic and Atmospheric Administration (NOAA), the National Undersea Research Program is a federally funded agency that provides unique state-of-the-art technology to scientists who are successful in a peer-review process. As a network of regional funding centers the National Undersea Research Centers represent a national resource in terms of the science they sponsor and the not insignificant amount of data collected. For the most part, this data pertains to issues of environmental and ecological significance and as such amplifies the importance of this information. It is therefore incumbent upon these regional centers, and the entire National Undersea Research Program (NURP) to maintain access to this data in a complete and timely manner. There are, no doubt, vast quantities of scientific data collected with public funds that sit in file cabinets and computer files throughout the country that will serve no further purpose simply because of ignorance of its existence, inability to integrate the data due to incompatible file format or original methodology used to collect the data. It is for this reason that the National Undersea Research Center at the University of Connecticut at Avery Point (NURC-UCAP) has begun a relational database management system (DBMS). The DBMS was based upon the needs of the most comprehensive data users/generators - the NURC-UCAP-funded scientists. A questionaire was distributed to these researchers to identify the data entities to be included in the DBMS. In this manner, utilization of the DBMS by other user groups (e.g. upper level government managers, political constituents, or the general public) is also accommodated since the information requirements of these groups can be synthesized from the more comprehensive data archives required by the scientists.

The DBMS was also designed with the intent to integrate the information into a Geographic Information System (GIS). The development of GIS's has rapidly evolved as computer hardware and software technology has leapfrogged in the past two decades. The reduction in cost of the hardware to the point that most resource management agencies (local, regional, and federal) can afford to have a machine with the processing power and storage capability of mainframes of a decade ago has facilitated the proliferation of GIS workstations to the point that they are becoming recognized resource management tools. Applications of these powerful tools to manage true marine-related data has lagged, however. Coastal applications are common, but the extension of the technology beyond the land-water boundary are, with a few exceptions only now beginning. The Canadian efforts in the Nova Scotian Fundy, Maine, and Georges project (FMG) arguably represent the most comprehensive and advanced program of this type in North America.

NURC-UCAP has initiated two pilot efforts in 1989 to attempt to link the processing and management power of GIS's with the unique data collected by in situ technology. The marriage of these technologies is facilitated by the fact that 85-90 % of the data collected by NURC-UCAP-sponsored scientists is from the benthos, i.e. the bottom of the ocean, and as such lends itself to the traditional two dimensional Cartesian geographic references utilized terrestrially. The data collected from the third and fourth dimensions, i.e. the water column and surface remain a challenge for programmers and data managers, although advances in the field of meteorology hold promise for three dimensional imaging of the water column.

The present structure of a relational database to collect the data at the field level, with subsequent integration into the GIS system is a viable means to link the two systems, since shipboard GIS's are not yet a reality. This also allows the relational DBMS to act as a stand alone entity that has utility for all user groups. The strength of the GIS is yet to be realized, yet represents an exciting advancement for scientists, resource managers, and the general public as means are developed to make these systems available and usable by all.

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APPENDIX A

THE NATIONAL UNDERSEA RESEARCH PROGRAM

OBJECTIVES

NURP is an integrated program focusing on research relating to processes in the world's oceans and great lakes in order to understand the global ecosystem that will then lead to forecasting in that system. The program promotes studies relating the use of ocean and lake resources to the ecosystem. NURP supports research programs within the following categories:

MAJOR RESEARCH THEMES

Global Oceanic Processes:

Determine and quantify the interaction of hot and cold seafloor vent systems with the chemistry, biology, and geology of the oceans; assess the effects of venting on a global spatial scale and a temporal scale from annual to millennia.

Pathways and Fate of Materials in the Ocean:

Determine the processes and flux of nutrients, metals, and organic waste material in the ecosystem and across the benthic boundaries of ocean and great lake basins.

Productivity and Habitat Characteristics:

Investigate the relationships of habitat characteristics and structure to faunal and floral productivity.

Coastal Oceanic Processes:

Study and evaluate the effect of phenomena including upwelling, ocean fronts, internal waves, and the sea ice edge on fisheries recruitment in regions such as banks, shoals, hardgrounds, reefs and submarine canyons; determine the role of these processes on sediment and nutrient cycling and transport along and across islands and continental shelves.

Ocean Lithosphere and Mineral Resources:

Define the rates and processes responsible for crust generation and consumption, determine the distribution of potentially valuable mineral resources on the sea floor particularly within the U. S. Exclusive Economic Zone (EEZ), assess the processes responsible for formations of ocean mineral resources and the impacts of their potential development.

Submersible Platform Technology:

Develop and implement new technologies to enhance the experimental and manipulative capabilities of researchers below the sea surface.

Diving Safety and Physiology:

Enhance the capability of divers to work beneath the sea, maintain a safe working environment, and determine the physiological effects (both immediate and long term) that limit the dives.

SYNOPSES OF THE FIVE NATIONAL UNDERSEA RESEARCH CENTERS

NURC at the Caribbean Marine Research Center

The National Undersea Research Center at the Caribbean Marine Research Center (NURC-CMRC) has facilities in Florida (Riviera Beach and Turkey Point on the Gulf of Mexico) and on Lee Stocking Island in the Exuma Cays, Bahama Islands. The Center is affiliated with Florida State University, University of South Carolina, Oregon State University, the Virginia Institute of Marine Science, and the United States Geological Survey. NURC-CMRC offers scientists a complete marine field laboratory with research opportunities in the Southeast United States, Caribbean, and Bahamian regions. The Bahamian location provides easy access to varied pristine marine environments including coral reefs, shoals, mangrove swamps, seagrass beds, deep hardgrounds, and carbonate mud beds.

Facilities include research ships, the PC-1401 submersible, the Shark Hunter wet submersible, a small habitat, and a Phantom-300 remotely operated vehicle (ROV). The Center has a variety of other facilities to support its research effort, including housing for permanent scientific and support staff, accommodations for small groups of visiting scientists and students, an experimental hatchery for rearing selected aquaculture species, a laboratory with computers, experimental and production tanks, airstrip, dock, boats, dive equipment, and a decompression chamber.

Major research programs include studying physical and ecological relationships in benthic environments at varying depths, developing scientific bases for rational habitat utilization through conservation and enhancement, defining ecological requirements of locally important species, and developing technology for low-cost aquatic food production.

NURC at the University of Connecticut at Avery Point

The National Undersea Research Center at the University of Connecticut (NURC-UCAP) offers marine and freshwater investigators the opportunity to use the most advanced underwater technology available for in situ research in support of basic and mission oriented science. NURC-UCAP conducts this research in the Gulf of Maine, off Southern New England, in the Mid-Atlantic Bight, and in the Laurentian Great Lakes. NURC-UCAP also plays a key role in the development and extension of sampling tools and technology for remotely operated vehicles and manned submersibles.

Research goals of NURC-UCAP include comparative analysis of biogeochemical and ecological dynamics of marine and freshwater systems coupled with the forecasting of effects of natural man-made changes on resource productivity and ecosystem functions. Typical projects focus on chemical, biological, and geological processes at the sediment/water interface along with the population and community ecology of benthic and midwater organisms. NURC-UCAP is conducting multidisciplinary research on ocean dumping of sewage sludge and its effects on productive benthic communities in the marine environment.

The Large Lakes of the World (LLW) Initiative is an extension of the Laurentian Great Lakes research. The program promotes far-sighted management of large U.S. and international freshwater lakes. The U. S. Great Lakes are being compared to other large lake systems with various stresses and ages, in terms of the biogeochemical processes affecting these systems. Cooperative research activities have been established in Israel, Kenya, and Malawi.

NURC at the Fairleigh Dickinson University

The National Undersea Research Center at Fairleigh Dickenson University (NURC-FDU) is located on St. Croix, U.S. Virgin Islands and in New Jersey. NURC-FDU conducts research in the Caribbean and in the Mid-Atlantic Bight. Projects supported by the Center utilize submersibles, remotely operated vehicles, shore-based facilities, and Aquarius, the world's only mobile saturation diving habitat for scientists.

At the forefront of NURC-FDU's success during the last decade has been the development and operation of two undersea habitats. The first habitat, Hydrolab, is now on exhibit at the Smithsonian Institution in Washington, D.C. It has been replaced by the mobile habitat Aquarius, which is currently located at St. Croix in a submarine canyon 18 meters underwater.

Aquarius accommodates five scientists and one staff member for up to ten days. Divers can spend over nine hours underwater per day at depths to 29 meters. Complete computer and electronic capabilities are available for use within Aquarius, as well as experimental laboratory benches, underwater video systems and AC and DC power to operate sophisticated analytical equipment. Living conditions in the habitat are extremely comfortable and include modern bathroom, kitchen and sleeping facilities.

Encouraging a multidisciplinary approach, the research goals of NURC-FDU are to contribute to the further understanding of marine coastal ecosystems. Research themes address the assessment and use of underwater resources. Areas of support include global climatic change, effects of pollution on coastal environments, and productivity of the oceans.

NURC at the University of Hawaii at Manoa

The National Undersea Research Center at the University of Hawaii (NURC-UH) conducts research on ecosystems and mineral resources of the Pacific Ocean centered around the Hawaiian Archipelago. The Center's facilities include remotely operated vehicles, a towed camera sled, a mission data repository, and the submersible Pisces V.

Pisces V is a three-person, one-atmosphere submersible with a maximum depth capability of 2,000 meters and a dive duration of up to eight hours. The submersible offers scientists direct observation, photographic and video capabilities, instrument placement, sample collecting, and environmental monitoring.

Pisces V is accommodated on a dedicated support vessel. Through the alternate use of the launch, recovery, and transport vehicle (LRT), the Center is able to launch and recover Pisces V in rough seas.

The NURC-UH interdisciplinary science program is focused on the natural ecosystems and resources of the Pacific Basin. Projects include the geology and biology of emerging and subsiding islands, marine product assessments, and Hawaiian fishery investigations of deep benthic shrimp and artificial reefs. Research is being conducted on processes of submarine mineral accumulations on seamounts, volcanoes, and islands. In addition, baseline information is being gathered on those deepsea marine ecosystems in the EEZ that could be affected by future mineral mining. The extent, chemistry, and dynamics of carbon dioxide and toxic effluent emanating from hydrothermal vents of submarine volcanoes and their contribution to global climatic and ecosystem changes is a programmatic frontier of the Center.

NURC at the University of North Carolina at Wilmington

The National Undersea Research Center at the University of North Carolina at Wilmington (NURC-UNCW) conducts research in the Southwestern North Atlantic Ocean and the Gulf of Mexico.

The basic operating philosophy of NURC-UNCW is to allow science to drive operational goals and directions of the Center. Due to the vast offshore area covered by NURC-UNCW and the varying subsea depths, topography, and conditions experienced, a multifaceted and flexible systems approach to undersea research is utilized. Center operations are carried out through a combination of leased and in-house facilities. Enriched air NITROX SCUBA and remotely operated vehicles are used in research along the relatively shallow continental shelf near the shore. Shallow and deep submersibles are used on the deeper continental shelf regions and on the upper continental slope.

The NURC-UNCW science program emphasizes research priorities of current national importance as well as the unique capabilities of in situ technology. The Center is conducting research on the effects of man's activities on the marine environment. Frontal eddies capable of carrying oil spills over the South Atlantic shelf and into shallow water are being studied. Research on communities that feed on hydrocarbons in Green Canyon seep sites may improve the ability to counteract oil contamination in the oceans. Other research projects include studies of global carbon cycling and phosphorite deposits. Evaluations of processes involved in maintaining high productivity of some important commercial and recreational fisheries are also being made.

APPENDIX B

QUICK - LOOK REPORT
NOAA's Office of Undersea Research
National Undersea Research Center

Mission Number: ______ Dive Number: ______ Date of Dive: ______

Date of Report: ______ Inclusive Dates of Mission: ____________

Project Title: ____

____

Principle Investigator: ______________________________________

Names of Senior and Supporting Investigators: _________________

____

____

I. Abstract of Dive Results:

* - Parts I, II, and III of this form may be omitted for those series of dives which support a single research investigation, provided the quick-look report for the initial dive has been completed and pertains to all subsequent dives in a series.

II. Please discuss the following:

Significance of the dive in relation to your specific research goals. General scientific contribution of the dive in terms of species and processes observed or measured, methodology and technology utilized.

Specific advantages of NOAA's Undersea Research Program to your research investigations.

Plans for use of the data gathered on this dive and the applications, products and/or benefits to NOAA.

III. Please include any comments on the following operational details, where applicable: weather and water conditions affecting operations, safety problems and concerns, dive management and personnel cooperation, logistics and support activities. If special sampling devices were supplied by NURC, please comment on their performance and suggest improvements.

____

Signature, Principal Investigator

APPENDIX C

ADDITIONAL RESPONSES TO QUESTIONNAIRE

RESPONSES WITHOUT FORMS

Principal Investigator	Comments
R. Langton:	Yes, good idea
B. Manny:	Limited utility/time consuming; question of availability of data upon request--made previous such request for data but got no response.
B. Vadas:	Good idea - no time to think of using it at present.
D. Fitzgerald:	Good idea - listed additional key words in memo.
R. Owen:	Good idea - see memo for comments.
T. Edsall:	Good idea, yes - might be good addition to Quick Look, see further comments in letter.
R. Huggett:	Yes, good idea - add under substratum...estimate of color (e.g., light, dark, etc.). Important if Ocean Dumping sites are studied.
G. Smith:	Yes, good idea.
P. Jumars:	No

RESPONSES WITH FORMS

Principal Investigator	Comments
H. Winn:	Personally, may not use, but someone summarizing might.
P. Sly:	Yes - record only essential info...Pg 2-4 not good because detail too limited for specific tasks, too great for quick-scan.

J. Bowers:	Yes - returned completed form, no comments.
M. Manson:	Yes, good idea - see comments.
W. Robinson:	Yes, good idea - see comments re format; may be good addition to Quick Look.
J. Krezoski:	Yes, good idea - if not excessive detail, a form will be useful.
D. Swackhamer:	Yes, good idea - maybe as addition to Quick Look.
C. Paola:	Yes - if I get involved with sub work again.
D. Hanisak:	Yes - add to Quick Look.
N. Hawley:	Yes, good idea - a little too specific, could cut down on keywords; could get good examples from AGU.
L. Boyer:	Yes - only if NURC archives and makes copies available of requested tapes.
D. Belknap:	Yes, good start - returned completed form.
R. Lewis:	Yes - returned completed form; should have geologic and oceanographic breakdown (see comments).
K. Nealson:	Yes, good idea - could be more general, see comments.
P. Lawton:	Yes, good idea - suggest it be post-mission report rather than add to Quick Look.
M. Youngbluth:	Yes - returned completed form with comments.
L. Mayer:	Yes - use depends on cost and ease of access.
J. Dearborn:	Yes, good idea - tough if added to Quick Look, see comments on form.
D. Campbell:	Yes - if data readily available.

R. Carlton:	Yes, good idea - comments on form.
F. Grassle:	Yes, useful - returned completed form.
R. Mann:	Yes, good list - good addition to Quick Look.
D. Lee:	Yes - suggested many additions, comments on form.
D. Jude:	Yes - see comments.

CHECKLIST OF POTENTIAL ADDITIONAL KEY WORDS

Principal Investigator/Key Words

P. Sly:

Date of Entry
Observer (insert under telephone no.)
Date of Dive
Video Tape Number(s)
Type of Dive (from pg. 2)
Delete Predive Activity & Comments
Samples collected/tasks performed
____ biota
____ other
Comments 2 & 3 (move/insert here)
Delete Substratum features to end of checklist

W. Robinson:

Repeat Dive (to same site)
____ this year
____ previous year
Samples collected/tasks performed
grabs
manipulators
set-up of experiments

D. Swackhamer:

Length of dive, hrs. = duration
Samples collected/tasks performed
biological samples

M. Youngbluth:

Video Tape Number
____ (# of dive, e.g. 1235 = n, n = 1....x,
if > 1 tape per dive)
Still photos
____ type of camera (e.g., Benthos, Hasselblad)
Scientist sphere
Scientist dive chamber
H2O Temp (° C)
Current (speed & direction)
Visibility (m)
Other environmental data (e.g., conductivity, chlorophyll)
Data logger profile
Samples collected/tasks performed
____ water samples
____ detritis samples
____ Type of Dive
____ water column (instead of midwater)

H. Winn:

CTD
Sonar Records
Frequency
Format
Fluorometer

D. Jude:

Video
____ available
____ not available

R. Mann:

Comments 2 & 3 (describe)
Substratum Features
____ rippled
____ anthropogenic material
____ wood
____ old nets
____ wrecks
____ etc.

M. Manson:

Samples collected/tasks performed
geological rock samples

D. Lee:

Samples collected/tasks performed
(expand list, see comments)

L. Boyer:

Type of Dive
fresh/marine
benthic
hard bottom
soft bottom

R. Lewis:

Type of Dive
Purpose of Dive (subject)
Substratum Features
diversity of bottom (homogeneous, highly variable, variable, slightly variable)

C. Paola:

Substratum Features
hard/soft mud bottom
rock outcropping
cross-section
cross-bedding
parallel lamination
bioturbation
bedforms
wave ripple
dunes
crag-&-tail
current ripples
linear groves
other current or wave markings
animal burrows & tracks

P. Lawton:

Organisms
familiar/unfamiliar w/ taxon
Actual Processes Studied

biogeochemistry
competitive interactions
predator-prey relations
animal behavior

L. Mayer:

Archive Samples
Analytical Data (after dive)
biological
chemical (organics, metals, etc.)
geological (grain size, etc.)
water samples (nutrients, etc.)

R. Carlton:

Algae
periphyton
epipsamic
epiphytic

Other Key Words:
Great Lakes
Nutrient Cycling
Microbial Ecology
Sediment
Nutrient Flux

J. Kelley:

Substratum Features
rippled bottom
ripple spacing
unusual features (single boulder in mud bottom, etc.)

APPENDIX D

FMG RESOURCE AND ENVIRONMENTAL ATLAS CONTENTS LIST

Title: Resource and Environmental Atlas of the Bay of Fundy , Gulf of Maine, Georges Bank Marine Region

1. INTRODUCTION

1.1 FMG - A Regional Perspective
1.2 Aim and Purpose of the Atlas
1.3 How to use the Atlas

2. PHYSIOGRAPHY AND GEOLOGY

2.1 Physiographic Regions
2.2 Bathymetry
2.3 Solid Geology
2.4 Surficial Geology and Bottom Sediments
2.5 Coastal Physiography

3. PHYSICAL AND CHEMICAL OCEANOGRAPHY

3.1 Tidal Range and Currents
3.2 Surface Currents (Winter/Summer)
3.3 Bottom Currents (Winter/Summer)
3.4 Surface Temperature (Seasonal)
3.5 Bottom Temperatures (Seasonal)
3.6 Density and Salinity (Seasonal)
3.7 Upwelling, Mixing and the Water Column
3.8 Wave Climate (Direction and Refraction)
3.9 Wind Climate and Storm Tracks
3.10 Phytoplankton
3.11 Zooplankton
3.12 Biomass Productivity

4. ECOLOGICAL RESOURCES

4.1 Marine Biogeographic Regions and Major Stocks
4.2 Lobster
4.3 Scallops
4.4 Clams, Mussels and Oysters
4.5 Herring
4.6 Other Pelagic Stocks (e.g., mackerel and squid)
4.7 Cod
4.8 Redfish
4.9 Pollock

4.10 Haddock
4.11 Other Groundfish
4.12 Salmon
4.13 Marine Mammals
4.14 Critical Coastal and Marine Habitats

5. POLITICAL AND ADMINISTRATIVE BOUNDARIES

5.1 Canada/USA Offshore Boundaries
5.2 State/Province/County Administrative Areas
5.3 Fishery Management Areas and Boundaries
5.4 Functional Boundaries (e.g., coast guard, air search and rescue)
5.5 Transportation and Pollution Control Areas

6. HUMAN RESOURCE UTILIZATION

6.1 Demographic Characteristics
6.2 Current Land Use
6.3 Transportation Links and Flows (Land, Sea and Air)
6.4 Sea Trade and Port Facilities
6.5 Onshore/Offshore Oil and Gas Development
6.6 Energy Linkages and Projects
6.7 Fish Catch and Landings
6.8 Fishermen and Processing Employees
6.9 International Fishing
6.10 Coastal Zone Industries and Employment

7. CRITICAL RESOURCE MANAGEMENT ISSUES

7.1 Development Pressures on the Coast/Marine Environment
7.2 Marine Pollution, Ocean Dumping and Dredging
7.3 Sites of Existing and Potential Aquaculture
7.4 Potential Impacts of Oil and Gas Development
7.5 Potential Impacts of Tidal Power Development
7.6 Potential Impacts of Depletion of Fish Stocks
7.7 Potential Impacts of Increased Shipping Transportation
7.8 Factors Affecting Marine Populations

APPENDIX E

AN OCEAN RESOURCE DATABASE FOR THE NATIONAL UNDERSEA RESEARCH CENTER AT THE UNIVERSITY OF CONNECTICUT AT AVERY POINT

PROGRAM DEVELOPMENT PROPOSAL

SUBMITTED BY:

Joe Kelly
and
Dan Belknap
Geology Department
University of Maine,
Orono, ME

and

Ivar Babb
NURC-UCAP

PROPOSED OBJECTIVES

Background

The National Undersea Research Center at the University of Connecticut at Avery Point sponsored over 40 science cruises in 1988 representing 211 dives that supported over 150 principal investigators, graduate students and technical staff. Since it inception in 1984 the number of dives sponsored by NURC-UCAP has increased about ten-fold and the total number of dives sponsored to date is 778. Each of these dives generated a vast amount of data that was stored in many formats including still photographs (both 35 and 70 mm) and video documentation, taped environmental data (e.g. temperature, salinity, turbidity, current, substrate etc.), audio tapes, bridge and principal investigator logs, and actual samples (e. g. voucher specimens, sediment, fluff, and water column) brought up from the various sites. These data formats represent a continuum ranging from "raw" environmental data that would be very useful to a researcher proposing to conduct research that is similar in theme or geographic location, to video/slide information to provide species, community structure information, to summary videos that would be useful for press releases, public relations, political support, and fund raising purposes. Unfortunately, only a small fraction is ever presented in the form of publications, presentations, or summarized in NURC annual and final reports. As the NURC expands and more investigators contribute their efforts, there is an increased demand for this type of information and a concomitant need to manage the data flow. Furthermore, as a publicly-funded program, NURC-UCAP is required to make the bulk of this information available upon request to the general public.

To make the database useable to the science community, however, requires accuracy and accessibility. A geographic information system (GIS) represents a state-of the-art development that stores multiple data types in a real world, spatial context. Based upon maps that are input via 9-inch tape, diskette, or drawn from a 2-dimensional tablet, the GIS is able to overlay environmental data (such as listed above) to determine areas where one feature coincides with another (e.g. presence of lobster over cobble substrate), to model (e.g. increase population of predators 2X=y abundance of prey in a given area), and potentially to predict long-term trends.

GIS systems are rapidly being established at major universities or state agencies throughout New England. The majority of states have adopted a system called ARC-INFO, and it is proposed, therefore, to use this system to guarantee flexibility and compatibility.

Objectives

The major objective is to establish a database management system that is easy to use (input and output), can deal with simple or complex datasets, is usable by a variety of groups, and is expandable to meet future needs.

1. Design the database per the needs of the NURC-UCAP, that can act as a "stand alone" system for NURC-UCAP use and that can eventually be integrated into objective two, below.

2. To assist in the development and implementation of the Arc-Info system at the University of Maine and to begin integration of simple data into this system as a proof-of-concept approach for subsequent demonstration and testing.

METHODS AND PROPOSED APPROACH

Database design

The design of any database should strive for simplicity and completeness to ensure that all potential users can easily access the type of data desired. The first step, therefore is to:

1. Determine the scope of the database, i.e. what kinds of information will it contain. What are the entities or fields (an entity can be any distinct object, e.g. videotape catalogues, publication references, substrate type, organism distribution etc.) comprising the database, i.e. what will be in the tables, lists etc.

The information in step 1 can be collected in the form of simple questionnaire sent to all PI's that have been involved with NURC-UCAP in the past 3-4 years. The questionnaire would simply ask for the entities (in the form of key words) that each PI feels would best suit his/her data requirements. The responses will be compiled and edited, and a list generated that would subsequently be returned to the PI's and sent out as a part of the RFP and the Quick-Look form. This key word checklist was sent out on October 27, 1988 to approximately 175 NURC-UCAP investigators. The response to the questionnaire was good, approximately 45 responses are presently being compiled.

Implementation of ARC-INFO

Several steps need to be taken to implement the ARC-INFO system, these include:

1. To purchase the computer tapes with the bathymetry of the Gulf of Maine and Southern New England from the NODC (National Ocean Data Center). These will serve as the foundation and information held in the database can then be superimposed electronically (or in hard output) over these baseline maps.

2. To hire a research assistant to input the information into the Arc-Info system at the University of Maine. An ideal person for this position would be a handicapped individual who is seeking an advanced degree in some branch of marine science, but is unable to conduct active field work.

The classes of information for this pilot effort minimally should include:

Date, dive number, observer(s), any predive activities, pilot name, system name, location (TD's of Loran C and latitude and longitude, including fixes taken during the dive), and cursory observations made (depth, water parameters - temperature, conductivity, transmissivity, etc., substrate type, and dominant fauna.

EXPANSION OF THE DATABASE

The scope of the database needs to be defined in terms of the entire Undersea Research Program. It is recommended, however, that this database management system be analyzed and emulated, as appropriate, for the national program and regional centers. Objective one above should consider the needs of the national office to track and have information available to answer requests for information from its constituents. The collective NURCs should also standardize a generic subset of information that all centers should try to maintain to begin to develop a national network. A minimal dataset should include an interchangeable list of geographic areas where dives have been made and the PI who made the dive. In addition, the individual centers will need to focus a more research theme and site-specific database to respond to their user communities.

The feasibility and utility of national adoption of the GIS component should also be considered. The ARC-INFO framework could be universally used and made accessible.

FUTURE CONSIDERATIONS

FIPS

A recent NOAA memorandum addressed the topic of digital cartography and stated that a Federal Information Processing Standard (FIPS) will be developed to standardize digital cartographic products, which could be used as a model for NURP.

NODC

An additional dimension to this aspect of the archive is the potential interface with the National Oceanographic Data Center which could be of value to initiate databases for the NURP programs. The NURPs could eventually contribute data to the NODC to complete the loop. The type of data archived by NODC includes: bathythermograph temperature profiles, and physical, chemical, and biological data for U.S. offshore and continental shelf areas.

BUDGET

1. Purchase of NGDC (National Geophysical Data Center) bathymetry tape, 1600 bpi, 9 inch	500.00
2. Full-time technician for data input, 6 months, University of Maine	4500.00
3. Database management software, (2 copies, UConn & U Maine)	1200.00
4. Indirect costs (35%) of item 2	157.50
TOTAL	$6757.50

APPENDIX F

LIST OF ACRONYMS

ASCII	American Standard Code for Information Exchange
AVHRR	Advanced Very High Resolution Radiometry
BLM	Bureau of Land Management
CARIS	Computer Aided Resource Information System
COMS	Center for Ocean Management Studies
CPU	Central Processing Unit
CTD	Conductivity, Temperature, Depth
CTDEP	Connecticut Department of Environmental Protection
DBMS	Database Management System
DOI	Department of the Interior
EEZ	Exclusive Economic Zone
ESRI	Environmental Systems Research Institute
FMG	Fundy, Maine, Georges (Bay of Fundy, Gulf of Maine, Georges Bank)
GIS	Geographic Information System
GOES	Geostationary Earth Orbiting Satellite
GPS	Global Positioning System
HSAP	High School Aquanaut Program
IDCCC	Interior Digital Cartographic Coordinating Committee
JSL	Johnson Sea Link (manned submersible)
LIS	Long Island Sound
LISS	Long Island Sound Study
LRIS	Land Registration and Information Service
LRT	Launch, Recovery, Transport
MIS	Management Information Systems
MUST	Manned Undersea Science and Technology
NBGIC	New Brunswick Geographic Information Corporation
NGDC	National Geophysical Data Center
NOAA	National Oceanic and Atmospheric Administration
NURC	National Undersea Research Center
NURP	National Undersea Research Program
PI	Principal Investigator
ROV	Remotely Operated Vehicle
USGS	United States Geological Survey
UTM	Universal Trans-Mercator