

A National Oceanographic Partnership Program Award

The Gulf of Maine Biogeographic Information System (GMBIS) Project

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<http://netviewer.usc.edu/web>

Long-term goals

The fundamental objectives of the GMBIS project are to develop a generic technical framework for marine biogeographic information systems assembly and an associated set of reusable software tools in support of the Census of Marine Life program (CoML) and its information management component, OBIS. More generally, GMBIS may be seen as model approach for oceanographic data management, integration, and dissemination across the Internet, and provide tools promoting new international and national standards for ecosystem-level approaches to marine resource management.

Objectives

Central to the development of an inventory of marine life and improved conceptual understanding of the mechanisms shaping species distribution patterns is the implementation of strategies aimed at enhancing assimilation and access to existing biogeographical information. The *Gulf of Maine Biogeographic Information System* project (GMBIS) is a joint initiative of the University of Southern California (USC, Los Angeles), Bedford Institute of Oceanography (BIO, Halifax) and the Atlantic Reference Center (ARC, St. Andrews) that has been funded for 2 years by NOPP under its "Census of Marine Life" program. Our objective is to provide a framework for the integration, visualization, analysis and dissemination of diverse types of biogeographical and oceanographic information. End-to-end viability of this approach is demonstrated in the context of a pilot application for the Gulf of Maine, a well-studied ecosystem for which extensive scientific data exists but one that historically has been subject to large-scale perturbation due to overharvesting. The project will be a proof-of-concept activity to explore how a geographical information system (GIS), internet and database technologies can be used to access and display integrated data products needed to address questions relating to the dynamics of species distribution patterns within the Gulf of Maine. Databases at the core of the information system include those of BIO, ARC and the North East Fisheries Science Center (NEFSC) at Woods Hole, which are the product of US and Canadian multidisciplinary research efforts over the last 30 years in the region. The development of GMBIS may serve not only as a model for the global Ocean Biogeographical Information System (OBIS), but it may also provide a powerful tool in support of new international and national demands for integrated, and ecologically responsible approaches to marine resource management.

Approach and work plan

Given that the GMBIS project was scheduled to end September of 2002, efforts during this final year focused on finalizing the detailed technical specification of the information system and

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associated software according to partnering end-user and perceived OBIS requirements. Emphasis was also placed on implementing the thematic focus of the GMBIS information system relative to two biogeographical storylines for the Gulf of Maine: a climatological characterization of the ecosystem, and a view of the interannual variability (temporal dynamics) of the system. Activities undertaken during this final phase included further software development, data product provision, GIS application development, web-portal enhancement, coordination work both within the GMBIS consortium and with the OBIS technical steering committee, and communication of project results at both national and international meetings. Refinement and addition of software capabilities to meet the needs of GMBIS and OBIS was undertaken by SSA (O'Brien) and BIO (Jerry Black/Bob Branton) for the EASy GIS and ACON software respectively. Data provision was by colleagues at both ARC (Van Guelpen – ARC museums collection database) and at BIO (Payzants-satellite imagery; Branton-fisheries data; Loder/Brickman and several other colleagues- physical, chemical and biological oceanographic datasets and climatological fields). Software requirement specification, and GIS application development/implementation was undertaken at USC (Tsontos). USC (Kiefer/Tsontos) also took the lead on aspects of project administration/coordination, and outreach at conferences and meetings. Activities over the past year have also entailed defining new directions for possible future work and collaborations with GMBIS partners and the broader OBIS community. Joint proposals were submitted that aim to use and further develop approaches and tools developed by GMBIS in new CoML/OBIS projects that are coming online (eg TOPP, GoM Census –electronic atlas).

Work Completed

This section describes technical work undertaken for the FY2002 in the areas of data provision, GIS application development, and software development.

Data Provision by BIO and ARC

The full range of datasets provided by our Canadian partners are summarized in the tables below by data type.

Physical Oceanographic Data Products

Data Types	Date Range/Freq.	Depth(s)	Spatial Extent	Format	Source
Bathymetry	NA	NA	GoM - Grand Bank	ASCII / DXF	BIO / Gebco
Salinity	Climatology Seasonal	0m, 30, max	GoM – Scotian Shelf	ASCII	BIO-SS
Temperature	Climatology Seasonal	0m, 30, max	GoM – Scotian Shelf	ASCII	BIO-SS
Density Differentials	Climatology Seasonal	0-50m, 0-max	GoM – Scotian Shelf	ASCII	BIO-SS
M2 Tidal ellipses (Zavg)	Climatology Spring	0-max	GoM – Scotian Shelf	ASCII	BIO-SS
Tidal Dissipation (Zavg)	Climatology Spring	0-max	GoM – Scotian Shelf	ASCII	BIO-SS
Current Vectors	Climatology Seasonal	0m, 30m, max	GoM – Scotian Shelf	ASCII	BIO-CH+SO
Temperature	Climatology Seasonal	0m, 30m, max	Cape Sable– Scotian Shelf	ASCII	BIO-CH+SO
Salinity	Climatology Seasonal	0m, 30m, max	Cape Sable– Scotian Shelf	ASCII	BIO-CH+SO
Normal Velocity	Climatology Seasonal	0m, 30m, max	Cape Sable– Scotian Shelf	ASCII	BIO-CH+SO
Turbulent Kinetic Energy	Climatology Seasonal	0m, 30m, max	Cape Sable– Scotian Shelf	ASCII	BIO-CH+SO

Satellite Imagery & Derived Products

Data Types	Date Range/Freq.	Depth(s)	Spatial Extent	Format	Source
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Biological Databases and Data Products

Data Types	Date Range/Freq.	Depth(s)	Spatial Extent	Format	Source	
					HDF Binary ASCII	BIO-LP BIO-LP BIO-BP
BIO Groundfish Survey DB	1970-present Spring, Summer	Multiple	GoM – Scotian Shelf	Access/Oracle	BIO-BB	
ARC Specify Specimen DB	Climatology Seasonal	Multiple	GoM – Grand Banks	Access/Excel	ARC-LvG	
In-situ [Chlorophyll]	Climatology Seasonal	0m, 10, 30 50 75, 100	GoM – Scotian Shelf	ASCII	BIO	
Zooplankton Biomass (Pseudo/Calanus by stage)	Climatology Bi-monthly	Zavg	GoM – Scotian Shelf	ASCII	MARMAP	
Ichthyoplankton Biomass (Cod, Haddock)	Climatology Bi-monthly Annual	Zavg	GoM – Scotian Shelf	ASCII	MARMAP, SEP SSIP, LHP	
Larval Fish Diversity (sp.Richness , Shannon's H)	Climatology Seasonal Annual	Zavg	GoM – Scotian Shelf	ASCII	MARMAP, SEP SSIP, LHP	
Adult Fish Diversity (sp.Richness , Shannon's H)	Climatology Seasonal Annual	Zavg	GoM – Scotian Shelf	ASCII	BIO	
Fish Abund. Distributions (10 key species)	Climatology Summer	Zavg	GoM – Scotian Shelf	ASCII	BIO + NMFS	

GMBIS GIS

Application Development in EASy

- Ingestion into EASy of full time series of bi-weekly satellite ocean color and thermal imagery for the period Sept. 2000 to Sept 2002 to complement existing imagery series (1997+) – see tables above.
- Assimilation in EASy of all physical, chemical, and biological data products relating to the GoM climatological characterization (themes 1) – see tables above.
- Ingestion into EASy of all physical, chemical, and biological data products relating to the interannual variability application for the GoM ecosystem (themes 2) – see tables above.
- Ingestion of the DFO-BIO groundfish survey database in support of the various GMBIS storylines.
- Extraction of georeferenced museums collections data from the ARC Specify database system for visualization and integration with other GMBIS data in EASy.
- Creation of EASy additional project databases and integration of relevant data from the various sources for each of the identified GMBIS scientific themes; development of associated GIS project files defining data variables and associated plotting parameters for each of these applications.

EASy Software Development for GMBIS (SSA)

- Upgrade existing routines to robustly ingest coastline/bathymetry datasets in Autocad DXF format for the study area from the GEBCO atlas.

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- Development of a tool to expose metadata of imagery files of diverse format.
- Development of bubble plotting capability for the visualization of spatial structure in the raw data (plot types include: sample station location, sample type presence absence/count/value/count-pie/value-pie charts).
- Development of capability to display the boundaries of selected imagery types
- Development of an image analysis tool returning aggregate statistics for user defined areas
- Development of a data credit capability – specific data in a project can be linked to a source and collaborator website that will appear as an acknowledgement when the data is viewed.
- Development of capability to capture and replay all graphically rendered database and computed imagery so as to speed up data visualization during project simulation and Internet data transfer, including data for XY-plots (depth profile, vertical transect contours, and time series).
- Development of a capability to link to external websites online hosting either static or dynamic content, and conducting context sensitive searches of online databases.
- Update of the NETVIEWER Internet client-server plug-in/service for EASy. Now multiple GIS applications developed with EASy desktop can be served across the Web from a single server computer hosting IIS, EASy, its Netviewer service DLL and SQL-server, which functions as the transaction manager. Both GMBIS GIS scientific storyline applications are web-enabled and can be viewed at: <http://netviewer.usc.edu/web/>
- Software testing: EASy and Netviewer.

ACON Software Development for GMBIS (BIO)

- Linkage of the groundfish survey databases of DFO and NMFS, and rendering them more accessible through the ACON Web- interface.
- Enhancement of the ACON interface and toolset, for example, to permit mapped overlays of groundfish abundance and ARC survey data with bathymetry and temperature data.
- ACON now also provides an interactive tool for selection and export of displayed data in various formats, including data files, imagery and video file formats.

Results

At its conclusion, the Gulf of Maine Biogeographic Information System project has developed a comprehensive range of products, both technical, archival, and conceptual, that are likely to prove of value to OBIS and the CoML. GMBIS has successfully assembled and tested a prototype information system facilitating dissemination, integration, and visualization of diverse existing biogeographic and oceanographic information for the Gulf of Maine available via DFO Maritimes ecosystems and museum collections databases, the OBIS portal and other certified online sources. GMBIS has developed a generic methodological framework for biogeographic

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information system design and implementation and a set of reusable software tools that can be easily ported and adapted to CoML applications elsewhere. In addition to demonstrating the viability of the technical system, adoption of a thematic focus in GMBIS has aided the communication of project achievements and has inherently resulted in a form of synthesis of knowledge of biogeographic patterns in the GoM in relation to environmental variability while also highlighting possible gaps in the existing information base.

The following sections briefly describe and illustrate some of the main outputs and deliverables resulting from the GMBIS project at its completion:

Communications

The following list summarizes key accomplishments in the areas of project outreach and result communication (a comprehensive listing of relevant meeting/workshops attended for GMBIS/OBIS is presented in earlier reports):

- Oral Paper on GMBIS at Colour of Ocean Data Conference, an international meeting on oceanographic data management approaches (Brussels, Belgium, 11/25-27/02) – Tsontos (USC)

Title: “The Gulf of Maine Biogeographical Information System Project – developing a spatial data management framework in support of OBIS”.

- Tsontos V.M & D.A. Kiefer. “The Gulf of Maine Biogeographical Information System Project: Developing a Spatial Data Management Framework in Support of OBIS”. *Oceanologica Acta.*, in press.
- Paper submitted and published in special edition of *Oceanography* dedicated to “Census of Marine Life” initiative: Tsontos, V.M. & D.A Kiefer. (2000) Development of a Dynamic Biogeographic Information System for the Gulf of Maine, *Oceanography* 13(3), 25-30.
- Significant upgrade of the GMBIS project Website (<http://netviewer.usc.edu/web/>) both in terms of content and appearance.

Key TECHNICAL OUTPUTS

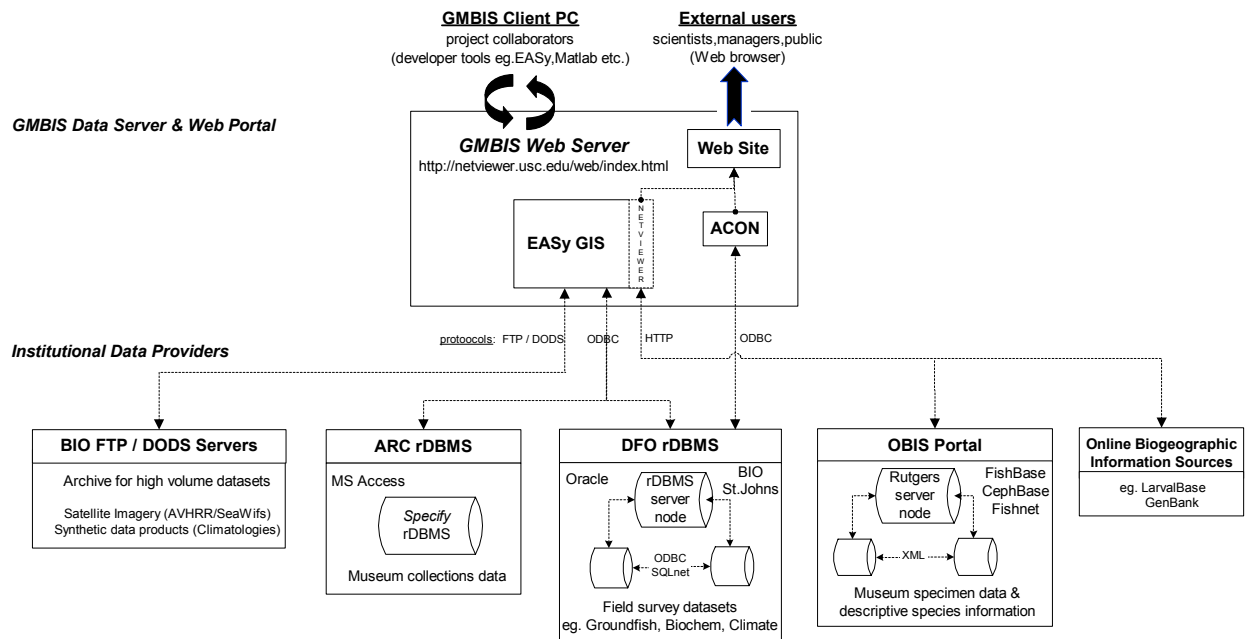
The Gulf of Maine Biogeographic Information System (GMBIS):

The components comprising GMBIS and the flow of information between the elements of this distributed information system are illustrated in the figure below. At the lowest level are the core data previously described that are held on diverse institutional servers and in a range of data archival systems. High volume datasets, not optimally stored within a relational database management system (rDBMS), are maintained and accessed in their native formats via FTP or DODS servers at BIO. These include chlorophyll concentration and SST satellite imagery, and synthetic data products generated at BIO and ARC in support of the scientific storylines. ARC museums collections data are accessed by GMBIS via the Specify rDBMS on which they are maintained. DFO ecosystems databases are managed, integrated, and disseminated via a network of interconnected Oracle database systems that serve the various DFO Maritimes laboratories. Complementary information on species distribution patterns and ecology is

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accessed directly by GMBIS from the OBIS portal via a context sensitive search mechanism, similar methods also being employed to query GenBank for genomic sample information.

The uppermost tier of the information system is the GMBIS web server providing broad, Internet-based access via the project website to value-added graphical data products, source data and descriptive GMBIS project information. The PC server computer hosts software tools (ACON and EASy Netviewer GIS) facilitating the assimilation, integration, visualization and dissemination of GMBIS core data by means of uncomplicated, interactive, graphical user interfaces. These tools ensure that external GMBIS users having only standard browser software (e.g. MS Internet Explorer) can interactively access GMBIS, visualize custom mapped data



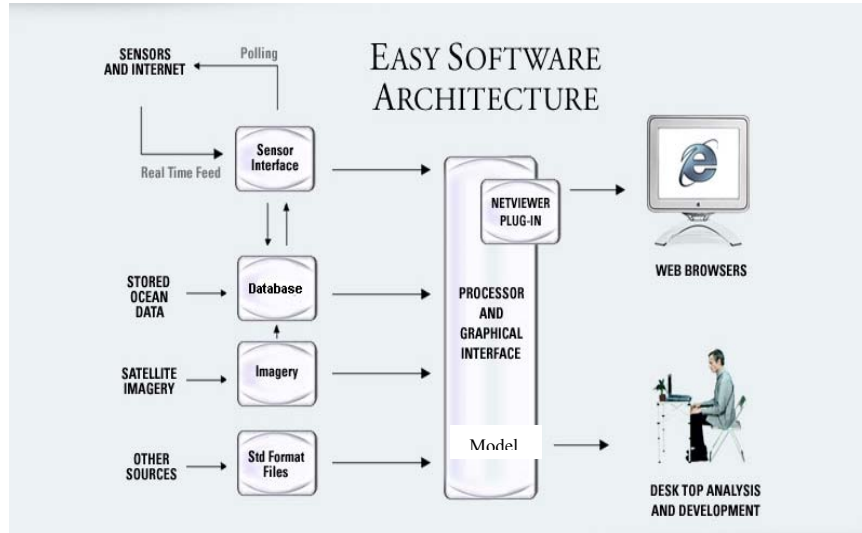
product sequences and download source data across the Internet.

Reusable Software Tools (EASy/Netviewer and ACON):

EASy (Environmental Analysis System), developed by System Science Applications in collaboration with the University of Southern California, is an advanced, geographical information system that has been specifically designed for marine applications and the handling of diverse types of oceanographic data. EASy is a PC Windows-based application (NT, 98, 2000, ME, XP) written principally in C++, but with Fortran, Java and Visual Basic component libraries. EASy supports the complete range of data access protocols implemented by GMBIS data providers, including ODBC (Open Database Connectivity), FTP (File Transfer Protocol), HTTP (Hypertext Transfer Protocol) and DODS (Distributed Ocean Data System) client functionality. It thus facilitates the integration of the full suite of available biogeographic and oceanographic information tapped by GMBIS (figure below). EASy's Netviewer Java plug-in component, facilitates the deployment of entire GIS applications on the Web such that external GMBIS users having only standard browser software (e.g. MS Internet Explorer) can dynamically operate the GIS, visualize custom mapped GMBIS data product sequences and

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download source data across the Internet. Use of EASy as a GIS web-server via Netviewer requires that the software be hosted on a PC running Microsoft IIS (Internet Information Services) server software. GIS project development is undertaken by GMBIS collaborators, who run EASy from their workstations



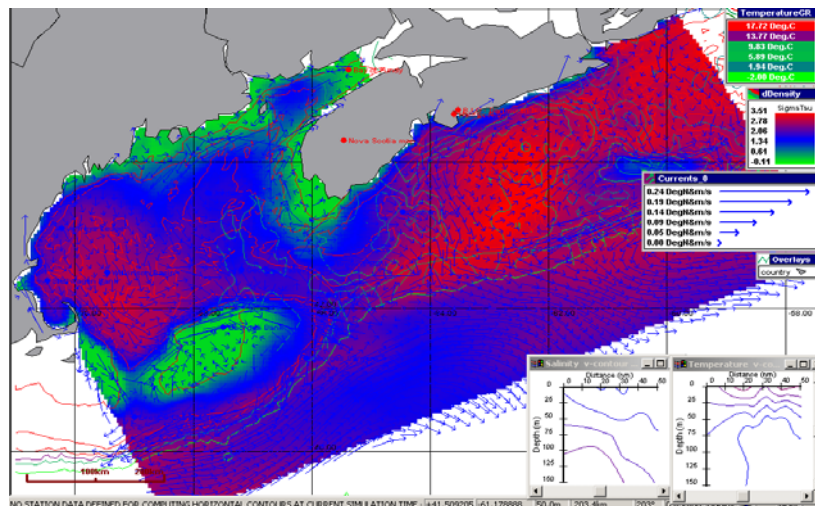
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ACON (A CONtouring) software, which was developed at the Bedford Institute of Oceanography, provides a web-based visualization front-end for an Oracle relational database system by supported ODBC, Oracle SQL/Net and CGI protocols via a script programming language. ACON contains a compiler and interpreter for a virtual machine based on an enhanced version of Extalk, and operates on VAX, UNIX, and PC Windows (95, 98, NT) environments. Both EASy and ACON exhibit the types of data integration, visualization and integration capabilities that are needed in marine biogeographic applications and oceanographic studies. These software comprise a reusable set of tools that can be leveraged effectively in other applications pertaining to the Census of Marine Life.

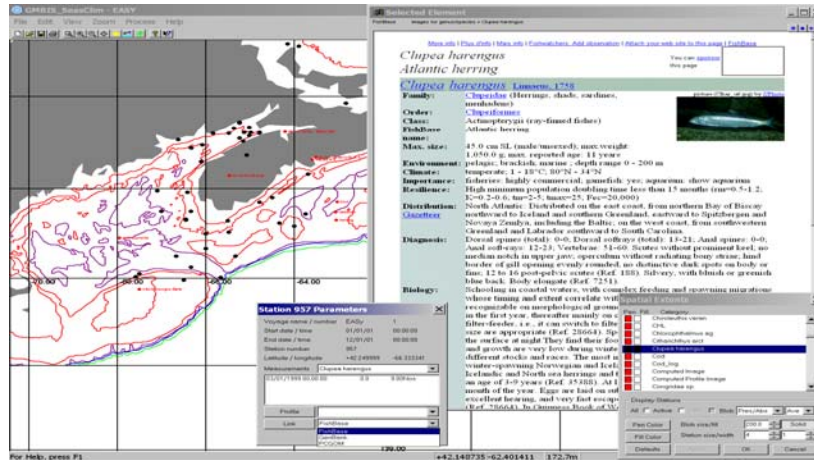
Data Products – A precursor to an electronic, online Atlas for the Gulf of Maine

An illustration of the types of integrated, graphical data displays that GMBIS provides is given in the following figure. The upper panel shows a seasonal climatological representation of the physical structure of the system for the summertime period.

Surface flow fields (vectors) here are overlaid with false colour data on water column mixing (surface:bottom density differentials). Temperature/salinity structure along a transect between Cape Sable and Georges Bank is illustrated as vertical contour plot (inserts). The lower panel displays the mapped distribution of herring (*Clupea harengus*) in the GoM from ARC archives. It also demonstrates parallel access to complementary biogeographic data and descriptive natural history information available on-line at the OBIS portal via EASy's Web-link and context-sensitive querying capability. GMBIS GIS applications and the full range of data associated data products can be accessed, visualized and downloaded by end-users across the Internet operating simply their Web-browser software.



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Impact and Applications

Quality of Life

The tools and content of GMBIS can lead to improved management of marine resources, including fisheries, mariculture, pollution, and coastal development, for the impacted Gulf of Maine ecosystem and beyond. GMBIS also provides a model technical framework and approach in support of the “Census of Marine” initiative that aims to characterize pattern of biodiversity in the world's oceans and the factors that shape them.

Science Education and Communication

GMBIS provide a framework for vastly improving the communication of marine environmental issues as well as instruction in the environmental sciences. I believe the potential here is very large.

Transitions

Quality of Life

Under NOAA sponsorship the software is currently being used to help develop an information system for better management of the groundfish fisheries of the Gulf of Maine, for the assessment of environmental impact of proposed penned fish farms in the Strait of Juan de Fuca, and for predictions of sea nettle blooms in Chesapeake Bay.

Science Education and Communication

The software is currently being applied to a broad range of educational and communication efforts. These include the development of

- Santa Monica Bay website for educating the public on water quality and the ecological health of Los Angeles’s urban coast (EPA)

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- exhibits for “Islands of the Pacific” for the Pacific Aquarium in Long Beach, California (private support)
- tracking tagged fish and analyzing environmental data from the tag’s sensors (private support)

Consideration for Excellence in Partnering Award

Ocean Sector Diversity: The partners in this project are the Wrigley Institute of Environmental Studies, University of Southern California, System Science Applications, a software development company in Los Angeles, the Bedford Institute of Oceanography, Halifax, Nova Scotia, and the Atlantic Reference Center, a marine museum in New Brunswick, Canada

Partner Involvement: The Bedford Institute of Oceanography (20% of total effort) and the Atlantic Reference Center (10% of total effort) contributed content and scientific themes (historical information on biodiversity in the Gulf of Maine), System Science Applications wrote computer code (30% of total effort), and the Wrigley Institute coordinated the project and assembled the system (40% of total effort).

Matching Contributions: System Science Applications and the Bedford Institute has contributed roughly a total of \$200,000 in software, and I estimate that the partners have contributed roughly one year of un-funded effort.

Partner Long-Term Commitment: The Bedford Institute has fully embraced the concept of applying environmental information systems to the management of Canada’s marine resources. Mark Costello, the director of the Atlantic Reference Center is Chair of the International Committee for the Census of Marine Life. System Science Applications and the Wrigley Institute are continuing there collaboration in developing information systems for the Census of Marine Life- currently working on the Sea Map Project, the Pilot Census for the Gulf of Maine, the OBIS portal, and the design of OBIS South America.

Success in Project Objectives: GMBIS has met and even surpassed all of the objectives stated in its proposal. Collaboration between and dedication by American and Canadian scientists could not have been better.

Related projects

A Groundfish Information System for the Gulf of Maine

A Marine Atlas for the Gulf of Maine (Pilot Census for Gulf of Maine)

OBIS SeaMap project (information system and global database of selected marine vertebrates)

Tagging of Pacific Pelagics (TOPP) – use of telemetry data to document movement pattern of selected fish species in the Pacific ocean.

In all of these projects, our role is to provide support in the area of information system design, database management, and GIS.

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Publications

Tsontos, V.M & D.A. Kiefer. "The Gulf of Maine Biogeographical Information System Project: Developing a Spatial Data Management Framework in Support of OBIS". *Oceanologica Acta.*, in press.

Tsontos, V.M. & D.A Kiefer. (2000) Development of a Dynamic Biogeographic Information System for the Gulf of Maine, *Oceanography* 13(3), 25-30.