SEAFLOOR MAPPING OF LONG ISLAND SOUND

SCOPE OF WORK - PHASE I: PILOT PROJECT

SUBMITTED TO:

THE LONG ISLAND SOUND CABLE FUND STEERING COMMITTEE

STATE OF CONNECTICUT, DEPARTMENT OF ENERGY AND ENVIRONMENTAL PROTECTION, OFFICE OF LONG ISLAND SOUND PROGRAMS;

STATE OF NEW YORK, DEPARTMENT OF ENVIRONMENTAL CONSERVATION, BUREAU OF MARINE RESOURCES;

CONNECTICUT SEA GRANT;

NEW YORK SEA GRANT;

AND

U.S. ENVIRONMENTAL PROTECTION AGENCY, REGIONS 1 AND 2

BY:
LAMONT – DOHERTY EARTH OBSERVATORY COLLABORATIVE
LONG ISLAND SOUND MAPPING AND RESEARCH COLLABORATIVE
NOAA’S OCEAN SERVICE COLLABORATIVE

SUBMITTED FEBRUARY 24, 2012

EXECUTIVE SUMMARY

The following Scope of Work represents an important milestone to successfully complete Seafloor Mapping of Long Island Sound. A project of this size has many challenges including but not limited to a large geographic project area, a diverse assemblage of collaborators, disparate past and present research activities, limited financial resources, and outcomes that are generally identified, but not explicitly defined. This document serves to provide the preliminary construct to more completely identify, define, organize and guide subsequent efforts.

The scientists from the collaborative consortiums which crafted this document represent a distinguished collection of experts that were able to reach consensus and identify the fundamental requirements needed to address the scientific and management objectives. The recommendations represent a range of activities designed to support the following outcomes identified in the August 2011 Prioritization Workshop:

- Key data sources required:
  - Bathymetry and backscatter
  - Biological and Physical Observational and sampling data
- Key derived products:
  - Geology
  - Benthic Habitats Characterization
  - Topography (e.g. Slope, Rugosity, and other relevant topographic metrics)

However, these components merely provided a broad description of the exact products needed, which the team subsequently further defined in developing this Scope of Work. The finalized list of products recommended to the Steering Committee, and described in detail later in this document, include:

- Acoustic Intensity (Section 6.0) - Acoustic intensity products are able to depict valuable properties about the composition, roughness, and texture of the seafloor to provide meaningful information to managers about the distribution and composition of seafloor habitats.
- Seafloor Topography (Section 7.0) - Seafloor topography products showing bathymetry and terrain relief are able to depict important features and seafloor changes to better explain physical, geological, and ecological processes.
- Benthic Habitat and Ecological Processes (Section 8.0) - Maps depicting seafloor habitats and their ecological communities are critical for many environmental management, conservation, and research activities, and for the growing focus on coastal and marine spatial planning. Such maps depict either separately or in combination the spatial distribution and extent of benthic habitats classified based on physical, geological, geomorphological, and biological attributes and the benthic communities that reside in the mapped habitats. Additionally, maps can be produced that depict ecological process across the sea floor.
- Sediment Texture and Grain Size Distribution (Section 9.0) - Mud, sand, and gravel dominated areas provide very different habitats and the main grain size often determines many seafloor characteristics. Therefore grain size composition and sediment texture of

the seafloor are essential elements of any habitat classification and detailed knowledge of grain size distribution is the basis for many management decisions.

- Sedimentary Environments (Physical) (Section 10.0) - Besides grain size the stability and suitability for different habitats for various species depend on the dominating sedimentary environment characterized by processes such as erosion, deposition, and transportation. Mapping and understanding these processes in detail is important for understanding habitats as well as their potential to change.

  and

- Physical and Chemical Environments (Section 11.0) Products that depict the distributions and variability of environmental characteristics like temperature, salinity, dissolved oxygen and bottom stress are central elements of habitat classification. They are also important to wise regulation and planning for dredging and other engineering activities in the coastal ocean.

In addition to the product sections, the Scope of Work also identifies project Coordination, Management, and Reporting constructs to guide partner interaction and implementation as well as a Data Management component to address the proper storage, organization and data access functions.

Finally, a broad-scale timeline, operational approach, and rough order of magnitude cost estimate have been developed (Section 12.0). These are preliminary estimates that will need to be refined with greater detail for the Cost and Technical proposals that will form the basis for the contractual elements. At this stage it will be incumbent upon the Steering Committee to provide any additional guidance as to the priority, perceived necessity, and cost proportioning of these elements before progressing to the next phase. Based on this guidance the next steps, Cost and Technical Proposals and Pilot Project commencement, will explicitly define how, when, cost, cross-collaboration, and the level of effort needed to deliver the needed products.

TABLE OF CONTENTS

1. BACKGROUND

1.1. The Long Island Sound Cable Fund

In June 2004, a settlement fund was created for the purpose of mapping the benthic environment of Long Island Sound (LIS) to identify areas of special resource concern, as well as areas that may be more suitable for the placement of energy and other infrastructure. This activity shall assist managers in the State of Connecticut, the State of New York, Connecticut and New York Sea Grant, and the U.S. Environmental Protection (USEPA) agency with their mandates to preserve and protect coastal and estuarine environments and water quality of Long Island Sound, while balancing competing human and energy needs with protection and restoration of essential ecological function and habitats.

At this time, the settlement fund consists of more than $7 million, which will be available for seafloor mapping activities over the next several years. In 2004, the Long Island Sound Study Policy Committee signed a Memorandum of Understanding on administering the fund for research and restoration projects to enhance the waters and related natural resources of Long Island Sound. In 2006, the Long Island Sound Study Policy Committee signed a second Memorandum of Understanding formally establishing a framework for the fund's use. The Policy Committee agreed that the Fund be used to: "Emphasize benthic mapping as a priority need, essential to an improved scientific basis for management and mitigation decisions."

1.2. The Long Island Sound Seafloor Mapping Workshop

The Connecticut Department of Environmental Protection (DEP) Office of Long Island Sound Programs (OLISP), the University of Connecticut Marine Sciences Department, and the EPA Long Island Sound Study hosted a Long Island Sound Seafloor Mapping Workshop in November, 2007 at Fort Trumbull, CT. The goal of the workshop was to identify and understand the research and management issues that would benefit from spatial data about seafloor conditions in the Sound, and was envisioned as the first step of developing a Strategic Seafloor Mapping Plan. Prior to the workshop the invitees were queried via a survey to identify the priority research and management needs, from which four major themes were identified in the following priority:

1. **Species and Habitats** – included reference to the seafloor areas or environments where organisms or ecological communities normally live or occur. This category also included identification of mapping needs for important species or biological communities;
2. **Infrastructure Projects**- included reference to/about structures placed in the Sound such as cables, pipelines, dredged sediment disposal sites, and structures placed to support aquaculture, docks, pier, and bulkheads;
3. **General Mapping & Ocean Management**- captured recommendations for mapping all of the Sound for a specific purpose. Ocean management was used capture concepts such as marine zoning, marine protected areas and reference (long-term monitoring) sites:
4. **Coastal Hazards & Geology** - included topics such as inundation from storm surge, shoreline erosion, and sedimentation. Also included here are search and rescue and dredged material management.

The most important features to be mapped included sediment type, bathymetry and habitat mapping.

1.3. Development of a Long Island Sound Habitat Classification Scheme

In 2008, the U.S. Environmental Protection Agency (EPA) funded Auster et al. to develop a Habitat Classification Scheme for the Long Island Sound Region (Auster et al. 2009). The report stated: "A habitat classification scheme defines the attributes of the environment used to characterize habitats and provides a common lexicon for identifying and mapping features at multiple scales and assessing dynamics overtime. Perhaps most importantly, use of a common habitat classification scheme serves as a foundation to communicate about resources and issues between various stakeholders and management groups." This habitat scheme was based on a web-based user survey of local, state, and federal managers, environmental policy-makers, researchers, environmental engineers, fishers, coastal developers, and those involved in energy infrastructure to ascertain the range of habitat attributes and resolution that they consider relevant to their work in LIS. The habitat attributes identified by the survey included: 1) Geoform features, 2) Sedimentary Features, 3) Biologic Features, 4) Boundaries, and 5) Integrative Attributes (Auster et al. 2009). Auster et al. proposed a modified habitat classification scheme based upon these attributes and a detailed evaluation of three habitat classification schemes (Greene et al., 1999, Valentine et al., 2005 and Connor et al., 2004) for their potential application in LIS.

1.4. Development of the Request for Qualifications and Interest

In April 2010, the State of Connecticut Department of Energy and Environmental Protection Office of Long Island Sound Programs released a Request for Qualifications and Interest (RQI). The RQI explicitly stated that this project will "address the need for acquiring, managing, interpreting, and making publically available datasets on the spatial distribution of benthic resources in Long Island Sound. The goal of the cooperative is to comprehensively map the bathymetry and surficial geology of the seafloor in Long Island Sound to help increase the understanding of seafloor habitat and improve resource management."

Subsequent to the announcement of the RQI, three entities were selected by the steering committee as interested and qualified to perform the activities needed. They include: 1) Lamont –Doherty Earth Observatory (LDEO) Collaborative, 2) Long Island Sound Mapping and Research Collaborative (LISMaRC), and 3) NOAA's Ocean Service Collaborative (Figure 1.1).

The collective State, Federal, and collaborative entities participated in a Spatial Prioritization Workshop (8/3-8/4/11) to capture and identify critical management applications of the information to be produced, spatial prioritization within Long Island Sound, and key data sources and derived products needed. One outcome of the Workshop was the identification of a staged project completion strategy in which Phase 1 would include a completion of a Pilot Project and Phase 2 would include completion of remaining priority areas in Long Island Sound.

Figure 1.1: LIS Project Team Organization

2. PHASE I PILOT PROJECT GOALS AND OBJECTIVES

There are two overarching goals of the Phase 1 Pilot Project: 1) Assess the Management of the Pilot Project and 2) define the Technical Components for the Pilot Area identified (Figure 2.1). There are many benefits of conducting a Pilot Project in LIS. There is great benefit in selecting a smaller geographic area to begin the focus of the project. This incremental strategy increases the success of the completing the larger LIS project area while simultaneously reducing the risk threshold of failure or impact of corrective measures if warranted. From the management perspective the Pilot Project will be assessed as to how well the structure facilitated meeting these objectives:

1) Establishing a coordinated teaming approach across the participating Consortiums;

2) Developing, implementing, and evaluating a technical approach, including logistics and QA/QC protocols;

3) Developing procedures that optimize the use of existing data products and data as appropriate;

4) Increase the opportunity of supportive data collection efforts by Federal agencies (i.e. NOAA); and

5) Providing metrics on the costs, logistics, and effort needed to produce the desired deliverables.

All of these elements will be reviewed by the LIS Steering Committee to determine if the Pilot Management Organization is workable and scalable to develop the work plan for the larger Phase 2 LIS effort.

The second goal of the Phase 1 Pilot Project is to define the technical elements of the Scope of Work that will assess the existing data, collect new data, evaluate new technologies for shallow water mapping, develop data products, design an information management system and provide public outreach. The Pilot Area was identified through consensus at the Spatial Prioritization Workshop and was chosen to capture as many elements of the anticipated project tasks and be as reflective of the larger LIS project area as possible. The objectives of this effort include:

1) Investigate and evaluate existing data and products that could be incorporated into data products;

2) Define the data acquisition approaches and standards for the key data (bathymetry, backscatter, biological/ecological and physical observations) and acquire additional data to fill existing gaps;

3) Test technologies and approaches for shallow water mapping;

4) Develop, assess and refine data products with a focus on the key derived products (geology, benthic habitat characterization and topography);

5) Implement and assess the Auster et al. LIS habitat classification scheme; and

6) Develop data management strategy (internal and external dissemination & archival).

The Pilot Project is intended to evaluate the entire process needed to complete the desired products on a subset of the larger LIS project area. It will include all data collection, analysis, data organization, and product development tasks that are anticipated to occur for the larger LIS project area. The suggested Pilot Project area is approximately 462 km^2 in size encompassing Connecticut and New York water between Bridgeport, CT and Setauket, NY.

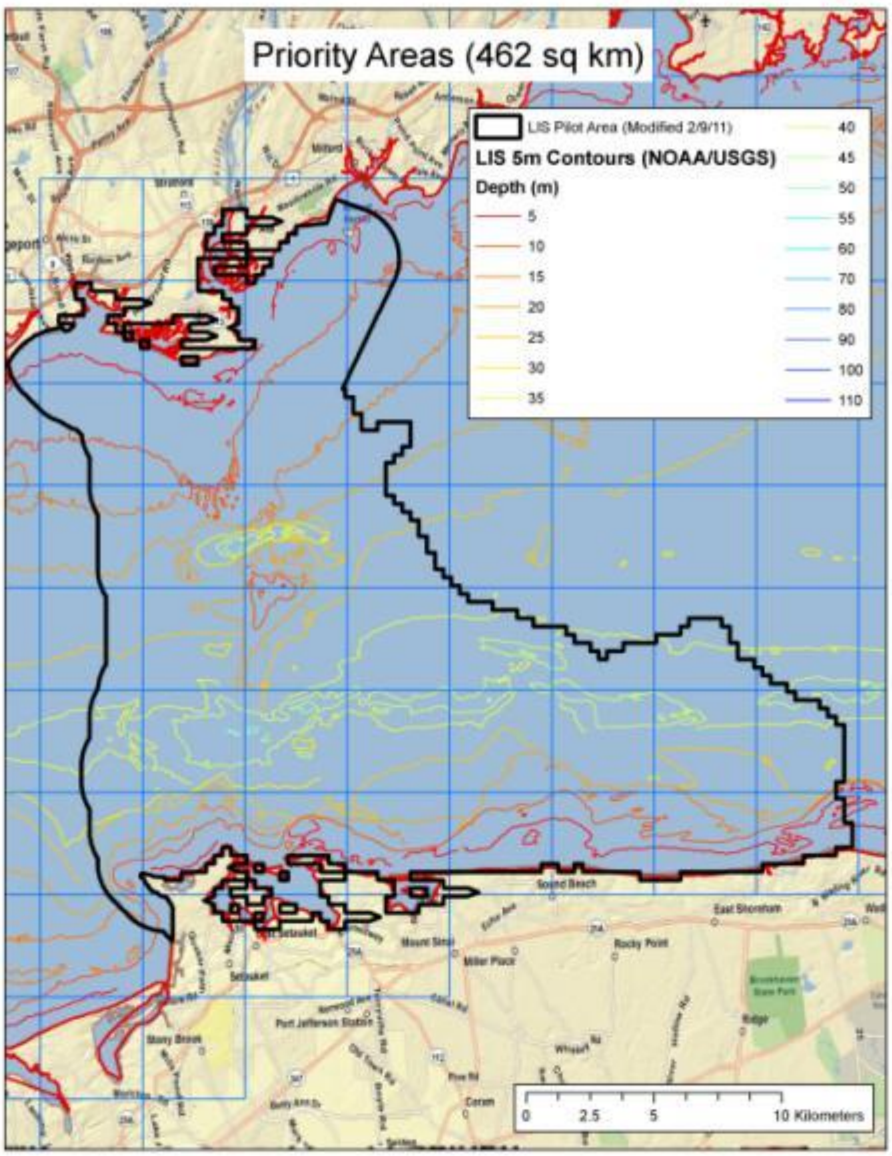


Figure 2.1: Pilot Project Area (462 sq km) for Long Island Sound

3. SCOPE

This Scope of Work (SOW) will provide for digital seafloor mapping and associated tasks of the Pilot Project Area for the Long Island Sound Cable Fund Steering Committee. This project will require the Contractor(s) to select a mapping approach; acquire imaging data; reprocess existing imaging data; delineate and field verify digital seafloor mapping data; delivery acquired imagery; and document methods and results such that the deliverables meet the technical requirements specified in the Scope of Work. The Contractor(s) will successfully complete all components of the project according to the following schedule 1) Phase 1A: Pilot Project Collection and Analysis; 2) Phase 1B: Pilot Project Report and Deliverable Submission; 3) Phase1C: Briefing to the Steering Committee on Pilot Project Outcomes. All aspects for successfully completing this effort by the Contractor(s) are to be presented in the Technical proposal. These aspects include all labor, equipment, supplies, travel, and materials associated with data acquisition, image acquisition, map compilation, quality control, spatial analysis, image processing, data documentation, writing reports, coordination, project management, and progress reporting, etc. required to deliver the final products. The components identified in the Scope of Work are intended to guide the Cooperative Teams in the development of their subsequent Technical Proposals.

4. DATA MANAGEMENT

The successful multi-disciplinary effort to map LIS will rely heavily on a well-coordinated data management effort. This includes coordination throughout the project and preparation of the data for integration into future product development efforts and permanent archives. We must ensure that:

- data are collected such that they can be broadly used for all aspects of the multi-disciplinary effort and are consistent enough to support interoperability;
- data are made available to members of the LIS Consortia to meet the goals of the project and produce the necessary products;
- data are sufficiently documented and stored to enable scientific discovery and facilitate management of natural resources within LIS well beyond the completion of the LIS mapping effort; and
- data are discoverable and easily accessible to a wide range of stakeholders (managers, scientists, public)

A well constructed data management system for the LIS Mapping effort will also enable interoperability with other on-line data resources, and will facilitate education and outreach efforts.

To accomplish this, the data management plan will establish:

- an inventory of data types,
- a data system
- a workflow integrating data with the data system,
- a data sharing policy

4.1. Data Summary

Figure 4.1 illustrates the conceptual organization and relationships between the expected data to be collected, the data processes, and required protocols:

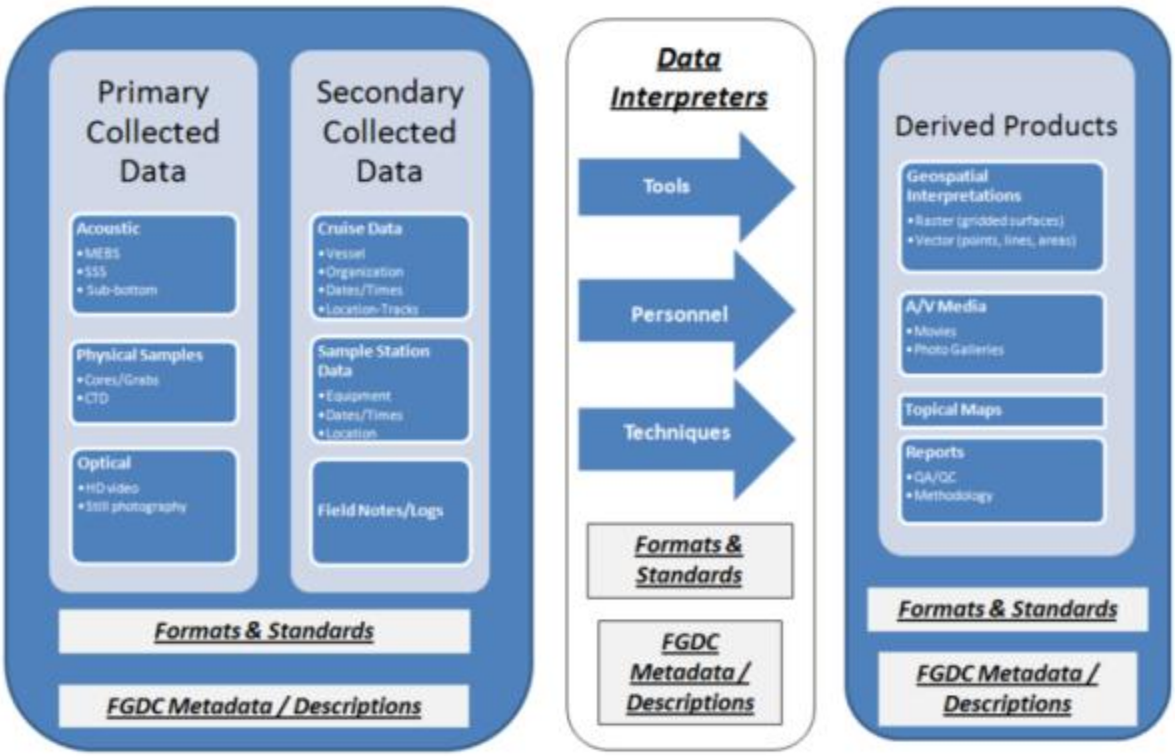


Figure 4.1: LIS Mapping Data Summary

The collected data is organized into *Primary* and *Secondary* types to distinguish between elements that directly relate to the physical environment studied via acoustics, physical sampling (e.g., geological, ecologic, physical, chemical) and optical methods (video, still photography) versus those which describe and monitor the act of data collection (e.g., field logs/reports, ship tracks, sampling stations/equipment, etc.). In concert these constitute *Raw Data* – first generation product used to create subsequent versions. Although these are not typically needed or required for future day-to-day operations, they nevertheless will be stored (archived) in a manner to preserve them in perpetuity and be accessible and available as needed. Where possible, the appropriate national repositories (National Geophysical Data Center, etc.) can be used; in cases where it is not possible to properly archive certain data, accommodations will be utilized within the data management system.

In advance of any data collection cruises, a common yet flexible data storage schema or file structure will be employed to organize the data at the point of collection making it easier to use in any automated data system tasks. Ensuring this commonality will also allow for easier data transfer and interoperability between the data system and among the project partners. This organizational structure will be developed in concert with partners but could potentially follow something similar to one described here (http://www.rvdata.us/operators/directory) with the caveat that this particular example was developed to leverage a specific, sophisticated process that the LIS collaborative would not necessarily employ.

Data Interpreters describe and control the methods by which the collected data is transformed into *Derived Products*. The interpreters themselves can be loosely described as tools (software, programming languages, etc.,) techniques (conversion algorithms, data transfer mechanisms, etc.,) and the people needed to generate the transformations. The derived products that result can be generally classified as geospatial products (GIS data layers,) and non-geospatial products (e.g. photos, video, topical maps, and reports.) These are more discretely described in the appropriate product sections. Taken as whole, they are the actual pieces of information that will be used with regularity to support management decisions and future research and field studies.

All data will conform to common *formats & standards* to ensure that all parties are producing output in a recognized, compatible, fashion commensurate with the required uses and audiences.

For data collection some elements (e.g. MBES and SSS acoustics) have well developed data formats and vetted standards (e.g., http://www.nauticalcharts.noaa.gov/hsd/specs/SPECS_2011.pdf.) In cases where a uniform or widely accepted standard does not exist, protocols will be developed by partner experts based on best professional practices/experience. In doing so, partners will collaborate to ensure that all collection standards are sufficiently acceptable, produce compatible results when collected individually, and to the maximum extent possible, can support multiple project needs (e.g., grab samples collected by different groups should be done in a consistent and compatible fashion to inform both geologic and ecologic assessments.)

For derived products some basic formats and standards taken from the product sections are compiled here:

Category	Data Type	Products	Preferred Format
Cruise Info	Cruise Tracks	GIS layer(s)	ESRI Geodatabase Feature Class (point/line/poly)
	Cruise Reports/Logs	Digital Documents	PDF
Acoustic	Acoustic Intensity mosaics (composition/roughness/texture)	Rasters	ESRI Grid, GeoTiff
	Topographic mosaics (bathymetry)	Rasters	ESRI Grid, GeoTiff
	Sub-Bottom profiles	GIS layer(s) & Rasters	ESRI Geodatabase Feature Class (line), JPEG
Sampling	Station Data (Biology/Geology/Chemical/Physical)	GIS layer(s)	ESRI Geodatabase Feature Class (point/line/poly)
	Video	Digital Movies	MOV
	Photos	Digital Photos	JPEG
Geospatial Interpretations	Ecological/Habitat Data	GIS layer(s)	ESRI Geodatabase Feature Class (point/line/poly)
	Sediment Texture/Grain Size	GIS layer(s)	ESRI Geodatabase Feature Class (point/line/poly)
	Sedimentary Environments (Chem/Organic/Inorganic)	GIS layer(s)	ESRI Geodatabase Feature Class (point/line/poly)
Maps/Reports	Analysis Reports/Summaries	Digital Documents	PDF
	Cartographic Maps	Digital Documents	GeoPDF

Standards:

- GIS layers data must have a defined data schema listing required attributes (e.g., unique IDs, Parent/child keys, legend/classification, dates/times, values, etc.) based on feature class types. Further, all features will be correctly attributed. This will ensure, for example, that all sediment grab data are organized and presented in the same way regardless of who collects or processes it.
- Where appropriate, all raster data of a common theme will be configured in the same fashion (e.g., number of bands, bit depth, symbology, etc.).
- GIS layers data will have topologically clean features.
- All data will be presented in common horizontal and vertical coordinate systems and projections.
- Where appropriate, all photos and video will be configured in the same fashion (e.g., number of bands, bit depth, quality/compression level etc.,).

Metadata will be prepared in an FGDC-compliant format for all *Derived Geospatial Products* produced during this project in accordance with Federal Executive Order 12906. Metadata records will include detailed information on field sampling dates, horizontal and vertical datums, projections, resampling algorithms, processing steps, field records, and any other pertinent information for all data and data products. Products will utilize accepted existing metadata templates when they exist. The metadata records conform to the Content Standards for Digital Geospatial Metadata as published May 1, 2000 by the Federal Geographic Data Committee (FGDC). Profiles and extensions to the standard that have been endorsed by the FGDC will be used if they are applicable. The metadata records shall contain all elements, including those considered optional, wherever applicable. http://www.fgdc.gov/standards/standards.html.

Some examples of appropriate metadata records can be found here:
http://www.cteco.uconn.edu/metadata/dep/document/HYDROGRAPHY_LINE_FGDC_Plus.htm
http://www.cteco.uconn.edu/metadata/dep/document/SUBREGIONAL_BASIN_POLY_FGDC_Plus.htm

4.2. Data System:

Integral to the success of any data management plan is the system by which the data will be maintained and accessed. To meet the needs of this effort, the data system should consist of the following:

- a data portal that meets the needs of the user community;
- a search interface based on keywords, parameters, or categories;
- map-based data discovery (e.g. geospatially enabled);
- archival of and access to raw and derived data products, project documentation, & FGDC metadata;
- web services for access, discovery and interoperability;

- a system for easy cost-effective ingestion of data/metadata/documentation;
- verification of data system integrity;
- the ability to provide access to derived product to other systems; and
- the ability to link to related data housed at other repositories.

Such a system should be designed to leverage existing technologies and platforms to enable efficiencies and economies of scale as well as reduce duplicative efforts. Figure 4.2 below presents a high-level organization of the basic concepts of a data system. Note the existence of a primary interface and suite of functions, access to metadata and all raw data and derived products, possible relationships between derived products and raw data, and the notion that data and products can exist both "internal" to the system as well as be accessible "outside" the system to external sources as needed. Examples of external sources could include discovery/visualization products such as the Northeast Ocean Data Portal or NOAA Digital Coast or perpetual data archives such as the National Geophysical Data Center or Data.gov.

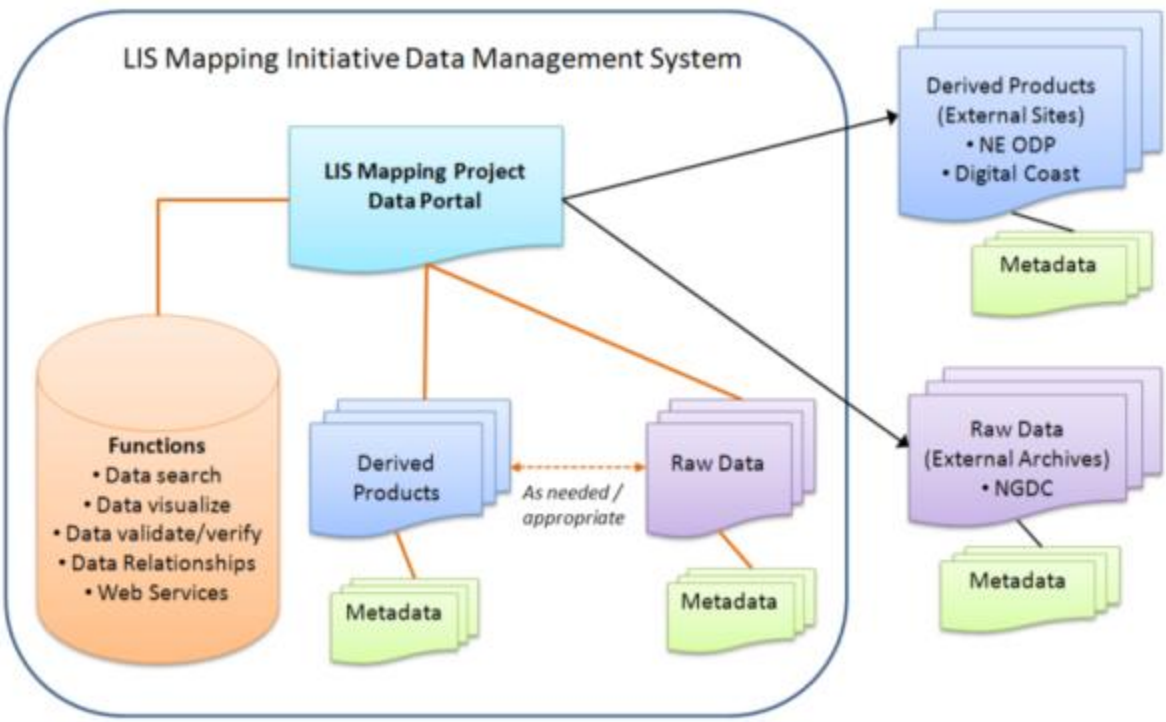


Figure 4.2: Basic Data System Concept

The links below identify some examples of existing operational systems that could be leveraged in whole or functionally integrated as needed/appropriate:

Data Portal Examples:

- http://www.marine-geo.org/portals/ridge2000/
- http://northeastoceandata.org/maps-and-tools/
- http://www.csc.noaa.gov/digitalcoast/

4.3. Data & Data System Integration Workflow

Figure 4.3 illustrates an idealized process by which data, partners, and the system interact. The process demonstrates a sequence of events and identifies some of the roles and responsibilities of the components.

- Steps 1a & 1b address the potential sources of raw data making the distinction between sensor data and physical samples. Partners collecting data will be responsible for providing data in the proper formats to the system. Since it is not advantageous to automate the data submission process at the point of capture (due to the variable platforms and equipment employed during a phased, multi-partner collection effort) the submission of data to the system would use a file transfer process (e.g., FTP, etc.) with each partner responsible for their data. In traditional approaches, partners would also be responsible for creating basic metadata records; however, leveraging existing data systems that can automate this process would eliminate this responsibility.
- Steps 2 & 3 illustrate the raw data stored in to facilitate easy and efficient sharing amongst partners without having to rely on their own organizational IT resources or infrastructure. Having a centralized system that can accommodate all data formats (or as many as possible) would present ease of use and other efficiencies so long as such a system was essentially in place and could be reasonably leveraged. In addition, basic metadata documentation for each data set available to LIS Mapping partners will be included and associated.
- Steps 4 & 5 address the ability for LIS Mapping partners to access any/all raw data sets necessary to create derived products by leveraging data system search and transfer functionality.
- Step 6 describes LIS Mapping partners submitting derived products and updated metadata records documenting the additional processing steps to the system via a file transfer process (e.g., FTP, etc.)
- Step 7 shows the integration of raw and derived product with potential external systems such as national/regional data discovery/data visualization sites or national data archives. At this stage the system should:
    - Store raw data that can’t be placed in an appropriate national archive.
    - Provide appropriate data to national archives.
    - Allow for the discovery (search) and access to (download) raw data via multiple ways (text/keyword interface, geospatial.)
    - Allow for the visualization of final product data in a geospatial web viewer (either within the system and/or shared to other systems that already have this capability.)
    - Allow for the ability to access all or parts of final products (either downloading entire data sets, or sub-setting them into sub-areas of interest.)

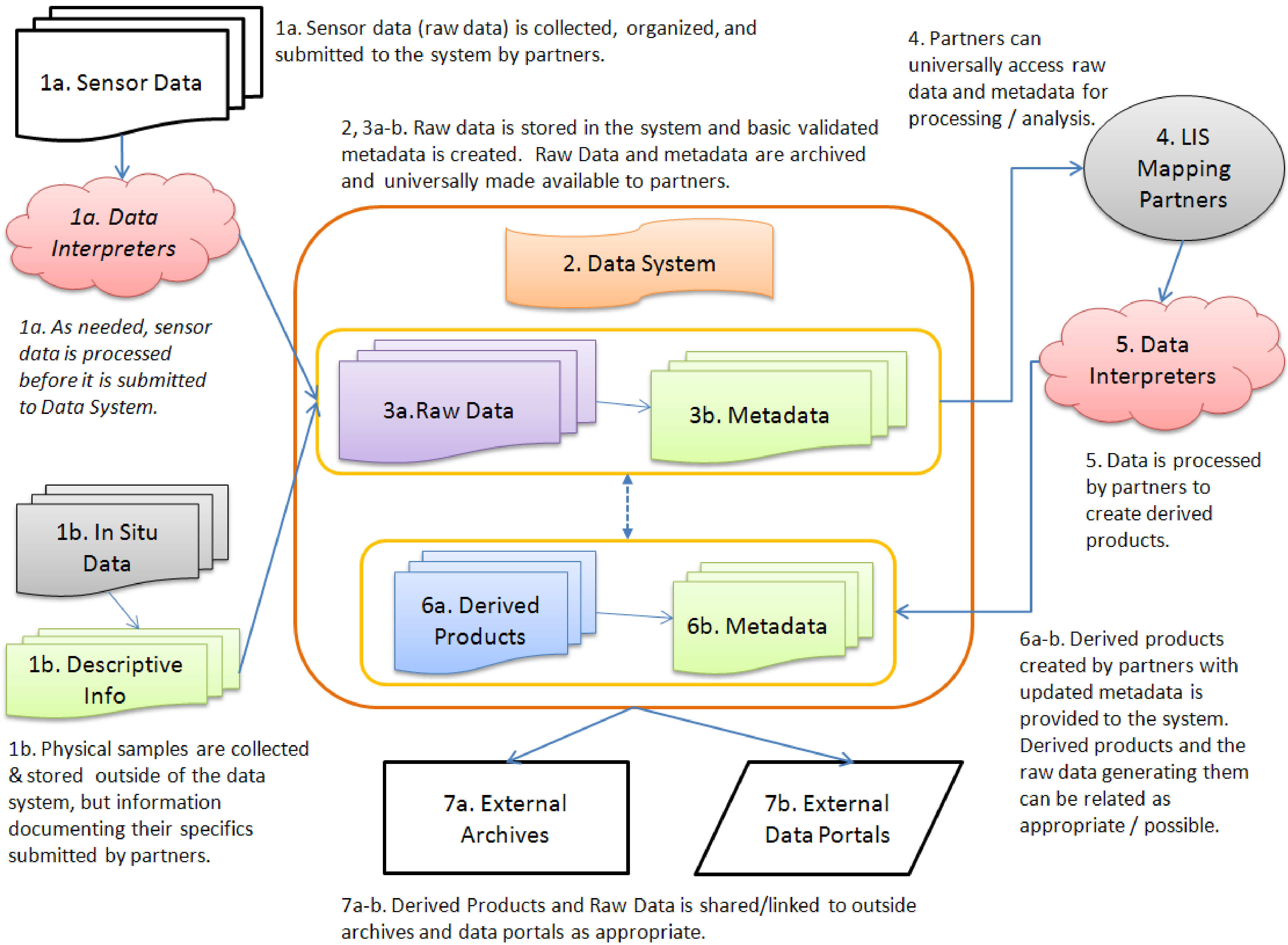


Figure 4.3: Data & Data System Integration – Idealized workflow

4.4. Data Agreement Policy

Due to the collaborative nature of the LIS Mapping effort, a data sharing policy will be required to ensure the maximum level of data management/processing interoperability and to provide for freely accessible data and derived products to the public. As such all parties shall agree that:

- All data (collected and derived products) will be publically accessible and freely available.
  - Collected data will be made publically accessible and freely available upon completion of derived products. Prior to being publically available, any collected data will be made freely accessible to members of the LIS Mapping Collaborative, but not necessarily the public at large.
  - Reasonable timeframes for processing of data into derived products will be established.
- In the event that a partner feels that some component of a data collection or processing step is proprietary, there will be a provision for an opt-out clause to protect any copyright or intellectual property rights. The existence of such a provision shall not in any way prevent the free and unrestricted access to any collected data, final data, or product.

4.5 Cost

It is anticipated that as much existing infrastructure as possible (e.g., hardware, software, tools, etc.) will be leveraged to reduce costs and take advantage of resources already in place. Despite this, there will undoubtedly be modifications required and additional costs incurred to handle workflows and tasks specific to this effort. The preliminary estimate listed below is gauged using a base allocation of approximately 5-7% of the entire pilot budget; the individual items provide an initial breakdown but should be considered somewhat fluid within the overall estimate. It should be noted that unknown start up costs may increase some or all of the pilot allocation estimates. However, the expectation would be that they provide utility beyond the pilot and into future phases.

Item	Estimate: (From Total Pilot budget of ~$1M)
Hardware	$7,500 - $10,500
Software	$2,500 - $3,500
Additional Development (portal/functions)	$25,000 - $35,000
Operations (personnel, maintenance)	$15,000 - $21,000
Total (assumes 5 - 7% of budget)	***~$50,000 - $70,000***

5. COORDINATION, MANAGEMENT, AND REPORTING

Successful implementation of all details of the Pilot project will require close coordination of all technical, logistical, and contracting components between the Consortiums and the Steering Committee. The following framework has been established to clearly articulate communication pathways between the groups (Figure 5.1). Technical Coordination will occur between the Consortiums, NOAA Technical Management (Tim Battista), and the Steering Committee designees (Kevin O'Brien CTDEEP and Charlie DeQuillfedt NYDEC). Each Consortium will be responsible for management and oversight of sub-group participants. The following principal investigators were designated through the RFI as management oversight leads for their respective Consortiums (Ivar Babb- LISMaRC; Frank Nitsche – LDEO, and Tim Battista – NOAA).

Coordination during the Pilot Project will be ensured through the combination of teleconference meetings, site meetings, and written status reporting. During the initial stages of Pilot Project, frequent communication is advised to ensure logistics and technical aspects are fully coordinated. Weekly teleconferences are planned for the first two months of the Pilot Project with an onsite meeting to also occur during the first two months. Thereafter, teleconference meetings will occur monthly between participants with and additional on site meeting to occur during this time period until the Pilot Project is complete. Additional meetings will be added as needed if extenuating conditions warrant more frequent coordination. Coordination and communication should occur between the various groups to maximize efficiency and cost effectiveness of ship resources, data collection, and investigative synergies.

Monthly Progress reporting will be submitted by each Consortium Principal Manager by the first Monday of each month during the duration of the Pilot Project. The purpose of the Monthly Progress reports is to inform the Steering Committee as to the actual progress to ensure that (i) the impact of delays of LIS seafloor mapping are mitigated, (ii) deliverables are submitted, reviewed, corrected, and/or approved in a timely manner, and (iii) the project is delivered on schedule. Each Monthly Progress Report will be transmitted by electronic format as an attachment to an email as a Microsoft Office Word 2007 for Windows document. All Monthly Progress Reports will be formatted to 8.5 inch x 11 inch page size with Times new Roman 12 point font. It shall include a cover page, narrative discussion of the contract progress organized by Sections specified below and shall be prepared to the same level of detail as the Contractor's Progress Plan submitted as part of their pre-award technical proposal.

The Content of the Monthly Progress Report shall contain the following:

- Cover Page containing the contract number and title; title of the report, sequence number of the report, and period of performance being reported; contractor's name and address; author(s); and date of the report.

- Section I – A description of overall progress plus a separate discussion of each task or other logical segment of work on which effort was expanded during the report period. This description shall include all pertinent data and/or graphs in sufficient detail to explain any significant results.

- Section II – A description of current technical, management, logistical or substantive performance and any problem(s) which may impede performance, along with proposed corrective action.

The Coordination, Management and Reporting elements will be evaluated by the LIS Cable Fund Steering Committee prior to commencing on Phase 2 of the LIS Habitat Mapping initiative.

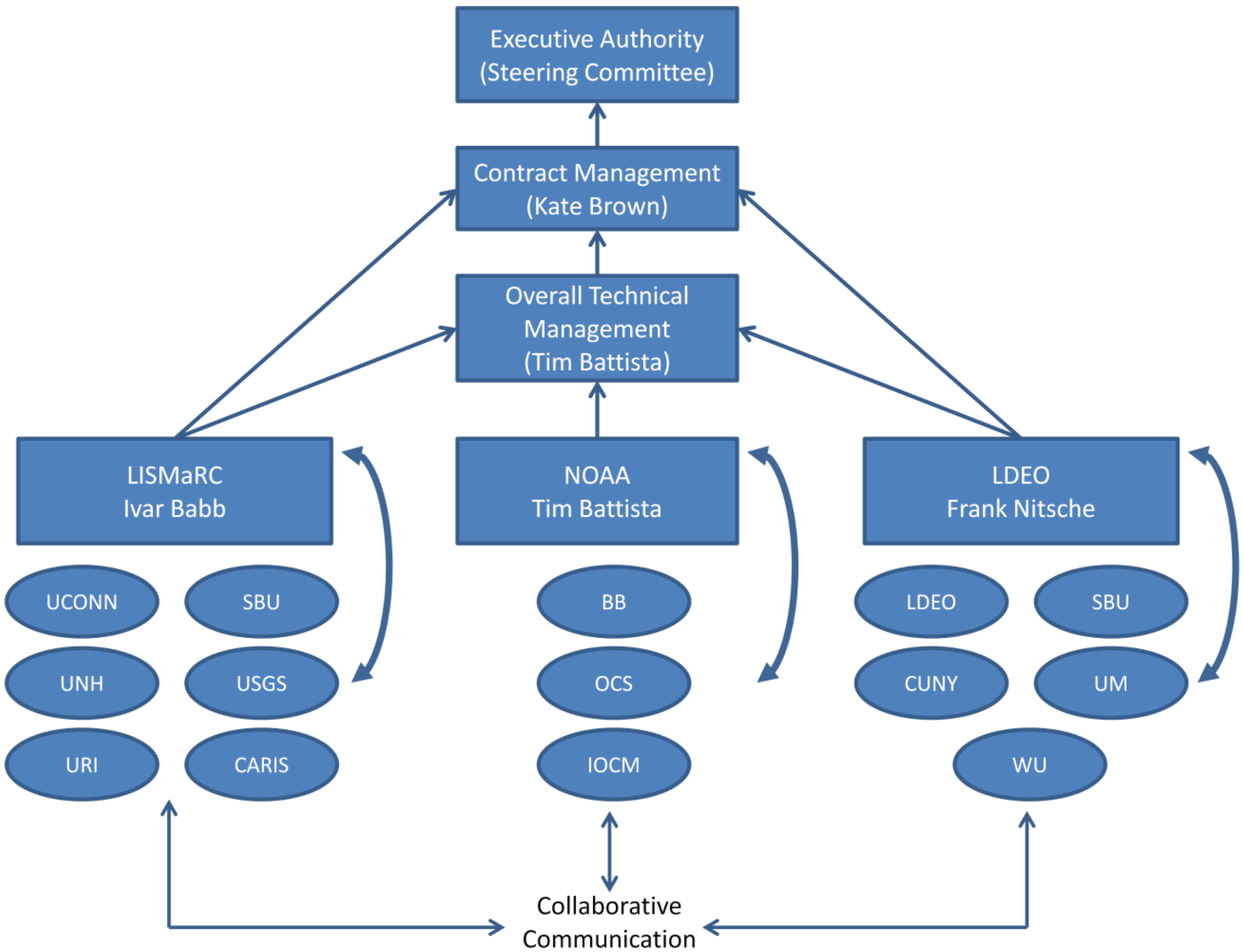


Figure 5.1: LIS Management Organizational Framework

DERIVED PRODUCTS:

6. ACOUSTIC INTENSITY

6.1. Importance/Need

Acoustic intensity maps are able to depict valuable properties about the composition, roughness, and texture of the seafloor. This product is a fundamental component necessary to satisfy the objectives of the LIS project. Data collected by sidescan or multibeam can be processed to provide meaningful information to managers about the distribution and composition of seafloor habitats. Additionally, acoustic intensity products can be combined with other data types (e.g. topography) to support the creation of additional products needed in LIS including benthic habitats, sediment texture and grain size distribution, and sedimentary environments.

6.2. Background/Existing Data

Maps depicting acoustic intensity from NOAA collected sidescan data have been produced for portions of the Pilot Project area by L. Poppe, USGS (Figure 6.1). To view these maps dynamically, please see the following URL:
http://ccma.nos.noaa.gov/explorer/msp/lis/msp_lis.html

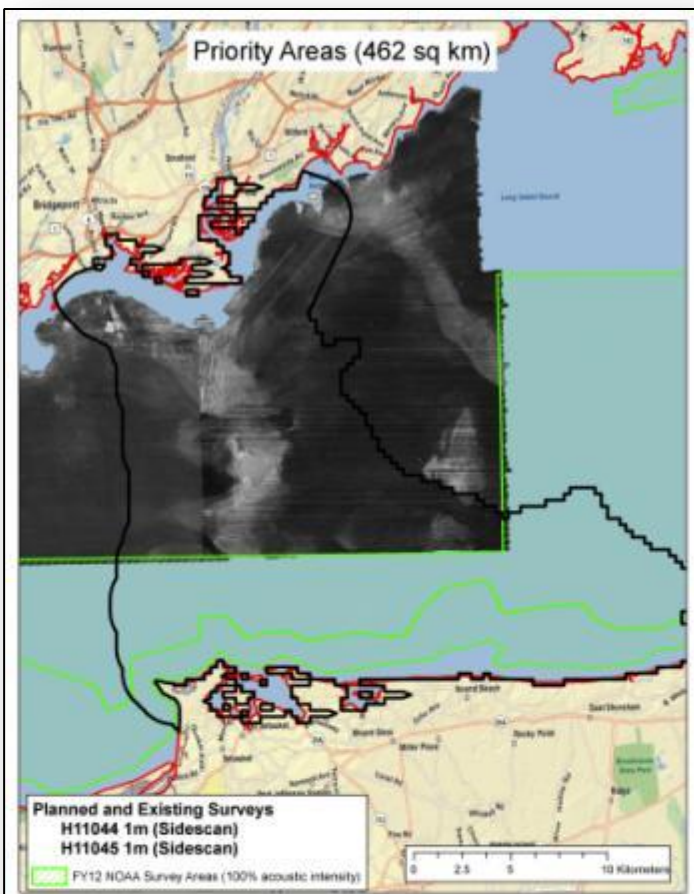


Figure 6.1: Map of sidescan acoustic intensity for the Pilot Project area in Long Island Sound.

6.3. Gap Analysis

6.3.1. Spatial and Temporal Coverage

While acoustic intensity mosaics of 65% of the Pilot Area have been completed, significant portions remain unmapped. In particular, the near shore environments (<4m) remain uncharacterized as well as the southern third of the Pilot Project area.

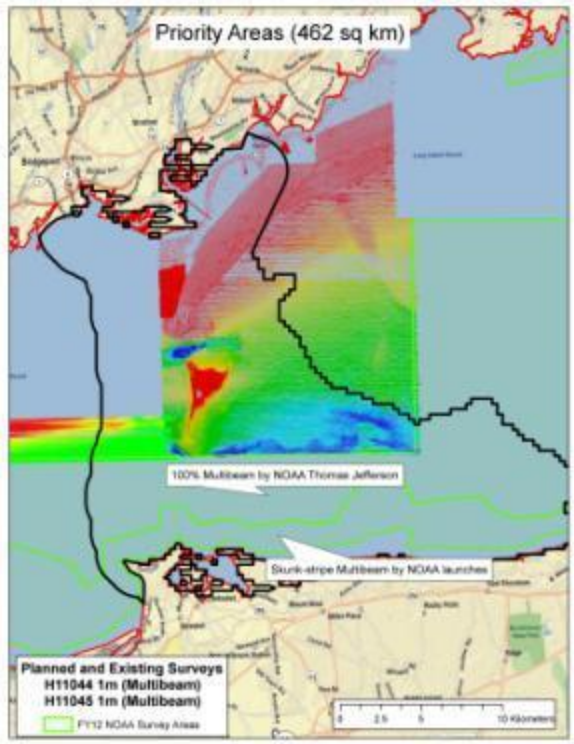


Figure 6.2: Map of NOAA Multibeam survey collections in LIS Pilot Project Area.

The mosaics shown (Figure 6.1) were based on data collected by NOAA in 2003 (H11045) and 2001 (H11044). Given the time that has elapsed since the data acquisition and the dynamic nature of the Pilot Project area, it is anticipated that significant changes will have occurred which will impact the accuracy of this data source if used to derive other products (e.g. benthic habitats). Furthermore, acoustic intensity maps were not derived from the swath multibeam datasets (Figure 6.2). It is assumed that new FY12 acquisitions to fill the coverage gaps will include the collection of acoustic intensity data which can be used to create acoustic intensity products. Improvements to the existing acoustic intensity data can be made through reprocessing using more contemporary software capabilities.

The spatial resolution of the existing sidescan acoustic intensity is suitable for mapping purposes (1m horizontal).

6.3.2. Suitability

The quality of the sidescan acoustic intensity mosaics is marginal. It is not entirely clear what processing approaches were used to generate the mosaics, but recent software advances offer significantly improved radiometric and geometric correction techniques. We believe significant improvements can be made to balance the intra- and inter-swath dynamic range of the existing data to provide a more consistent and normalized product. Additionally, a product integrating the existing and newly acquired data will be produced to ensure optimum acoustic intensity value consistency across the multiple survey areas.

6.4. Required Data

The following contains a description of the type of data necessary to produce this product.

6.4.1. Existing Data

Acoustic intensity mosaics are needed to inform and strategize sampling effort for a number for the other components. These legacy datasets already exist for portions of the Pilot Project area (Figure 6.1), but will be reprocessed to provide an improved more useful product. It is our intention to re-use these existing datasets to the extent possible, but improve their utility.

6.4.2. New Data

Acoustic intensity data types are standardized in the industry. It is anticipated that new NOAA or academic partner acquisitions will follow the procedures described in detail in the NOAA Publication Surveys: Specifications and Deliverables (NOAA 2011).

6.4.2.1. Collection methods

To increase the spatial and thematic resolution of a benthic habitat map for the Pilot Project area, new bathymetry and backscatter imagery should be collected covering 100% of the seafloor in areas were acoustic imagery is missing or legacy datasets are unusable. A suite of sensors should be used to collect this imagery, including multibeam echosounders (MBES), side scan (SSS) and interferometric SoNARs (PDBS). The most efficient acoustic sensor for mapping an area will depend primarily on the desired products (i.e., bathymetry, backscatter or both), the survey depths and the maximum allowable vertical and horizontal uncertainty requirements.

6.4.2.2. Existing Standards and Guidelines

There are existing standard operating procedures and specifications for collecting bathymetry and backscatter (NOAA 2011, IHO 2008).

6.5. Delivered Product(s)

The following contains a description of the type of product that will be provided.

6.5.1. Raw Product

Raw products should be collected according to the NOAA Publication Surveys: Specifications and Deliverables.

6.5.2. Interpreted Product

6.5.2.1. Geospatial imagery and shapefile products

This product will include backscatter surfaces that are geometrically corrected for navigation attitude, transducer attitude and slant range distortion, and radiometrically corrected for changes in acquisition gains, power levels, pulse widths, local seafloor slope and ensonification areas. GeoTiff mosaics will incorporate all of the individual sonar swaths. Acoustic intensities will be balanced across all surveys where different sonar frequencies were used and beam pattern corrections applied. This task will incorporate the existing data, new data to be collected by NOAA, and new shallow water data to be collected by the academic partners to provide a seamless integrated product. The horizontal resolution of the mosaics will optimally be 1m, unless precluded by data that was collected at a coarser scale. In this instance, the resolution will be dictated by the lowest resolution dataset.

Separate intensity mosaics should be created using decibel and relative 8-bit (0-255) values. Intensity values should be encoded such that low backscatter pixels have lower values and high backscatter pixels have higher values. To the extent possible, the mosaics will select swaths or portions of swaths so as to minimize the propagation of smearing, noise fraction, or other artifacts that may be apparent in the source data.

6.5.2.2. Geospatial map products

Digital cartographic plots (format GeoPDF) will be produced depicting intensity return of bottom coverage. These maps should be properly attributed with standard cartographic elements and data source references.

6.5.3. Reports and Documentation

The acquisition of new data for the Pilot Project Area by NOAA will include the generation of a Descriptive Report and Data Acquisition Processing Report. Any additional processing conducted to produce the acoustic intensity products will require detailed narrative description about the data sets used and methodologies implemented to generate the product.

6.6. Cost and Time Estimate

It is anticipated that NOAA's Office of Coastal Survey (OCS) will collect additional data in the Pilot Project area in FY12. OCS has agreed to begin collection within the Pilot Area first before proceeding to other areas in LIS to an effort to support needed information. While they will provide final cleaned bathymetry, they will not provide acoustic intensity products. Therefore NOAA Biogeography Program will be responsible for producing preliminary derived products to disseminate to the other collaborative partners. However, the very shallow water component will need to be collected and processed by academic partners and also subsequently provide preliminary products to the collaborative partners. All of the existing and new data will need to be incorporated into a common database and unified to provide a seamless product. In addition, report writing and map making for new and existing data for the entire seamless dataset will be necessary. It is anticipated that new data collections will require 30 days of NOAA time, and 30 days of academic time. Preliminary data post-processing of the newly acquired data will require 30 days to complete. Reprocessing of the existing datasets will require 30 days to complete. Final integrated data processing will require another 15 days to complete, and 15 days of report writing and map making.

6.7. References

IHO (International Hydrographic Organization. 2008. IHO Standards for Hydrographic Surveys. (5th edition). http://www.iho.int/iho_pubs/standard/S-44_5E.pdf, pp. 36.

NOAA. 2011. Hydrographic Surveys: Specifications and Deliverables (2011 Edition). http://www.nauticalcharts.noaa.gov/hsd/specs/SPECS_2011.pdf, pp.175.

7. SEAFLOOR TOPOGRAPHY

7.1. Importance and Need

Bathymetry is an important base environmental layer for spatial planning since it influences both planning of human activities (e.g., construction, shipping) and many physical, chemical and ecological processes. Producing highly resolved and accurate bathymetric products with continuous coverage of the surface area is a critical component for this project. Producing seafloor topography products will require the utilization of existing data sets (single beam and multibeam), but also integration with newly acquired data to provide consistent and comprehensive outputs. This product is a fundamental component necessary to satisfy the objectives of the LIS project. Data collected by interferometric, single beam or multibeam can be processed into meaningful information to managers, but can also be combined with other data sources (e.g. acoustic intensity) to provide a multivariate solution. Seafloor topography products provide critical information to support the creation of other product types needed in LIS including benthic habitats, sediment texture and grain size distribution, and sedimentary environments.

7.2. Background and Existing Data

Maps depicting interpolated seafloor topography from NOAA collected single beam and multibeam data have been produced for the pilot area by L. Poppe, USGS (Figure 7.1). To view these maps dynamically, please see the following URL:
http://ccma.nos.noaa.gov/explorer/msp/lis/msp_lis.html

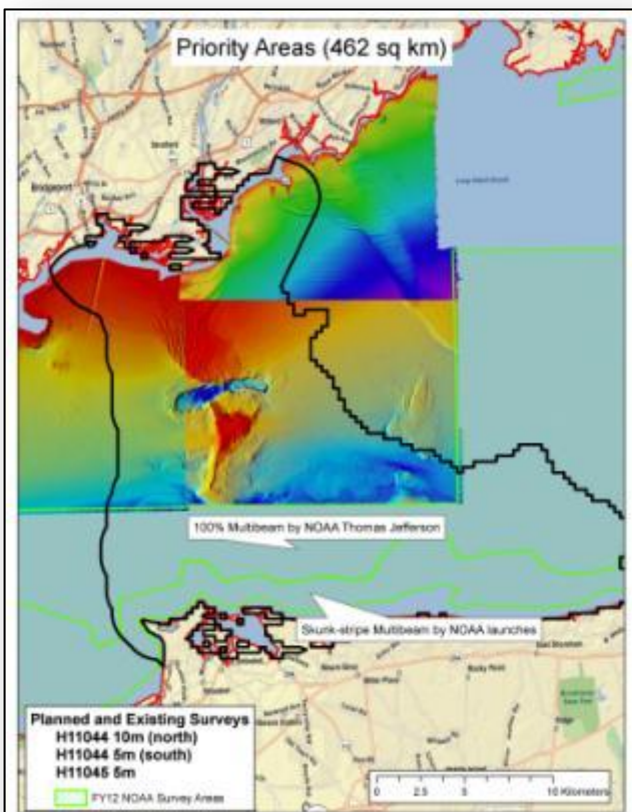


Figure 7.1: Map of interpolated seafloor topography for the pilot area in Long Island Sound.

7.3. Gap Analysis

7.3.1. Spatial and Temporal Coverage

While interpolated seafloor topography mosaics of 65% of the Pilot Area have been completed, significant portions remain unmapped. In particular, the important near shore environments (<4m) remain uncharacterized as well as the southern third of the Pilot Project area.

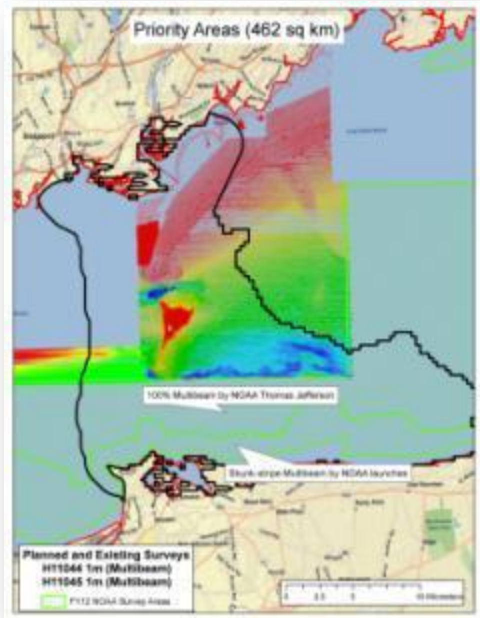


Figure 7.2: Map of NOAA Multibeam survey collections in LIS Pilot Project Area.

The mosaics shown were based on data collected by NOAA in 2003 (H11045) and 2001 (H11044). As seen in Figure 7.2, NOAA did not collect 100% multibeam coverage for these surveys. Typically 200% sidescan and single beam bathymetry are acquired for the entire project areas and swath bathymetry used to develop topographically complex features. This “skunk striping” approach, while time efficient and useful for identifying danger to navigation, does not provide 100% swath acoustic coverage of the seafloor. Thus the interpolated seafloor topography products are based on modeling of the single beam and multibeam data, providing estimated, but not actual depths where data is absent. NOAA FY12 planned survey by the NOAA ship Thomas Jefferson (TJ) will acquire 100% multibeam (and acoustic backscatter) coverage for moderate depth areas shown. Based on recent discussions, there is a strong likelihood they will also implement 100% multibeam coverage of the shoaler areas to be covered by TJ launches.

The spatial resolution of the existing interpolated seafloor topography (5m and 10m) is unsuitable for fine scale mapping purposes. The grid resolution of the bathymetric grids will optimally be 1m in water depths 0-20 m, 2m in water depths 20-40 m, and 3m in water depths 40-80 m, unless the geostatistical uncertainty model indicates a coarser resolution is necessary. Finally, other seafloor topographic metrics are lacking for the Pilot Project area that would need to be produced (e.g. curvature, plan curvature, profile curvature, rugosity, slope, slope of slope, Bathymetric Position Index (BPI) and Topographic Roughness Index (TRI). All of these topographic metrics, including BPI and TRI, use varying geostatistically methods to derive and highlight different terrain aspects of the seascape.

7.3.2 Suitability

While the quality of the NOAA bathymetry data is excellent, the spatial coverage of swath multibeam is an impediment to producing a high resolution continuous surface that is not reliant on interpolation methodologies to fill in data gaps. Spatial interpolation can be useful for depicting general patterns in seafloor topography, it is unable to adequately model absolute topography or small scale spatial patterns. It is recommended that an assessment of the impact of incomplete bathymetric coverage will have deriving other components. We propose to reprocess and use the existing data for preliminary sampling plan design, but also evaluate these datasets to determine their suitability. The current cost (Section proposal assumes that these existing are insufficient to support analysis and that data gaps will need to be filled. However, once these data are reprocessed and evaluated, they may be determined to be sufficient for use and therefore additional collection unnecessary.

Additionally, more highly resolved bathymetric coverage is required for new areas where data gaps exist and possibly of previously mapped areas of greatest management concern. Significant data gaps occur in the shallow water (<4m) shoreward southern and northern portions of the Pilot Project area.

7.4 Required Data

The following contains a description of the type of data necessary to produce this product.

7.4.1 Existing Data

Improved seafloor topography models are needed to improve the continuity of existing acoustic surveys (H11044 and H11045, Figure 7.1). While the present state of these data is sufficient for preliminary planning efforts, these legacy datasets will need to be reprocessed before being used for habitat mapping. To enhance their utility, they should also be integrated with new data to be collected to provide a seamless integrated dataset.

Given the patchwork of data collected in the Pilot Project area and variations in data density, a geostatistical modeling approach (e.g. kriging) should be implemented to predict a continuous, gridded bathymetric surface from scattered raw sounding points and to generate corresponding spatially-explicit uncertainty estimates. The spatial resolution of the existing seafloor topography products generated by L. Poppe USGS needs to be improved using more robust spatial modeling techniques that can determine the maximum resolution possible and the uncertainty associated with the derived model. Presently these products are at 5 m and 10 m horizontal resolution.

In addition, other topographic grids will also be derived by implementing geostatistical techniques using the bathymetric grids as a source. The resolution of these grids should match that of the source bathymetric grid. The following topographic derivative grids (format GeoTiff) will be produced (or others as deemed useful): bathymetry (mean), bathymetry (standard deviation), curvature, plan curvature, profile curvature, rugosity, slope, slope of slope, BPI and TRI.

7.4.2 New Data

Acoustic intensity data types are standardized in the industry. It is anticipated that new NOAA or academic partner acquisitions will follow the procedures described in detail in the NOAA Publication Surveys: Specifications and Deliverables (NOAA 2011). The NOAA

FY12 effort will achieve data coverage in the Pilot Project to the 4m isobaths. The collection to be completed by NOAA will satisfy 95% of the Pilot Project area and should be considered sufficient for most purposes. However if the very shallow water areas is deemed necessary for meeting the objectives of the Long Island Sound effort, then these locales will need to be satisfied by the academic partners. In addition, an evaluation of areas previously collected by NOAA where 100% bathymetry was not collected need to be evaluated to determine if that will be satisfactory. In the event it is not, additional surveys will needed to be completed by the academic partners to fill in "skunk-stripe" gaps. This can be determined through the selection of representative areas of overlap between the existing data and newly acquired data.

7.4.2.1 Collection methods

To increase the spatial and thematic resolution of a benthic habitat map for the pilot area, new bathymetry and backscatter imagery should be collected covering 100% of the seafloor in areas were acoustic imagery is missing or if reprocessing of any legacy datasets does not provide results that are unusable. A suite of sensors should be used to collect this imagery, including multibeam echosounders (MBES) and interferometric SoNARs (PDBS). The most efficient acoustic sensor for mapping an area will depend primarily on the desired products (i.e., bathymetry, backscatter or both), the survey depths and the maximum allowable vertical and horizontal uncertainty requirements. Every attempt will be made to ensure consistency in data collection across platforms and survey group through the use of accepted acquisition and processing guidelines (NOAA 2011).

7.4.2.2 Existing Standards and Guidelines

There are existing standard operating procedures and specifications for collecting bathymetry and backscatter (NOAA 2011, IHO 2008).

7.5. Delivered Product(s)

The following contains a description of the type of product that will be provided.

7.5.1. Raw Product

See NOAA's Hydrographic Surveys: Specifications and Deliverables (2011 Edition) for more details about these standards.

7.5.2. Interpreted Product

7.5.2.1. Geospatial imagery and shapefile products

Bathymetric grids will be produced for the Pilot Project area. The resolution of the bathymetric grids will optimally be 1m in water depths 0-20 m, 2m in water depths 20-40 m, and 3m in water depths 40-80 m, unless the geostatistical uncertainty model indicates a coarser resolution is necessary. Depths will be stored as negative floating point values submitted as GeoTiff digital image files as well as exported to an ascii X,Y,Z file. All images shall be created from fully corrected data that have been cleaned of all anomalous soundings Table 7.1). This task will incorporate the existing data, new data to be collected by NOAA, and new shallow water data to be collected by the academic partners to provide a seamless integrated product.

Other topographic grids (Table 7.1) will also be derived by implementing geostatistical techniques using the bathymetric grids as a source. The resolution of these grids should match that of the source bathymetric grid.

Topography	Topography describes the classified (high, medium, low) structure complexity of the seafloor as derived from bathymetry.
Class Name	**Definition**
Depth (mean)	Average water depth within a specified neighborhood.
Depth (Standard Deviation)	Dispersion of water depth values about the mean within a specified neighborhood.
Curvature	Degree to which the seafloor deviates from a flat surface withing a specified neighborhood. Curvature highlights ridges, crests and valleys.
Plan Curvature	Curvature of the surface perpendicular to the maximum slope direction withing a specified neighborhood.
Profile Curvature	Curvature of the surface parallel to the maximum slope direction withing a specified neighborhood.
Rugosity	Ratio of seafloor surface area to planar area withing a specified neighborhood.
Slope	Rate at which seafloor depth changes withing a specified neighborhood.
Slope of Slope	Instantaneous rate at which seafloor slope changes within a specified neighborhood.
TRI (topographic roughness index)	Zonal measure of depth deviation of adjacent neighborhood cells around a central bathymetric point.
Unknown	Habitats that are indistinguishable in the acoustic imagery due to noise in the bathymetry and/or backscatter or other interference with the acoustic signature of the seafloor.

Table 7.1: Table denoting additional topographic grids to be created for the pilot area in Long Island Sound.

7.5.2.2. Geospatial map products

In addition to delivery of the bathymetric grid, three types of digital, cartographic swath coverage plots (format GeoPDF) for the project area will be produced; one plot depicting color by depth of bottom coverage and two plots depicting sun-illuminated images of the area ensonified. Each sun-illuminated image shall depict data illuminated from orthogonal directions 90° apart, using a light source with an elevation no greater than 45 degrees. At a minimum, 24 bit color depth shall be used for compilation of the color by depth and sun-illuminated images, with a colormap to highlight the depth variations.

Digital cartographic plots (format GeoPDF) will also be produced for the topographic derivatives (bathymetry (mean), bathymetry (standard deviation), curvature, plan curvature, profile curvature, rugosity, slope, BPI, TRI, and slope of slope).

These maps will be properly attributed with standard cartographic elements and data source references. The map symbology will capture and sufficiently distinguish the thematic elements being displayed.

7.5.3. Reports and Documentation

The acquisition of new data for the Pilot Project Area by NOAA will include the generation of a Descriptive Report and Data Acquisition Processing Report. Any additional processing conducted to produce the acoustic intensity products will require detailed narrative description about the data sets used and methodologies implemented to generate the product.

7.6. Cost and Time Estimate

It is anticipated that NOAA's Office of Coastal Survey (OCS) will collect additional data in the Pilot Project area in FY12. OCS has agreed to begin collection within the Pilot Area first before proceeding to other areas in LIS to an effort to support needed information. While they will provide final cleaned bathymetry it is unlikely the timeframe for delivery will be sufficient to support planning efforts for other components. Therefore NOAA Biogeography Program will be responsible for producing preliminary derived products to disseminate to the other collaborative partners. However, the very shallow water component will need to be collected and processed by academic partners and also subsequently provide preliminary products to the collaborative partners. All of the existing and new data will need to be incorporated into a common database and unified to provide a seamless product. In addition, report writing, map making for new and existing data, and creating topographic derivatives for the entire seamless dataset will be necessary. It is anticipated that new data collections will require 30 days of NOAA time, and 30 days of academic time. Preliminary data post-processing will require 30 days to complete. Final integrated data processing will require another 15 days to complete, and 15 days of report writing and map making.

7.7. References

IHO (International Hydrographic Organization. 2008. IHO Standards for Hydrographic Surveys. (5th edition). http://www.iho.int/iho_pubs/standard/S-44_5E.pdf, pp. 36.

NOAA. 2011. Hydrographic Surveys: Specifications and Deliverables (2011 Edition). http://www.nauticalcharts.noaa.gov/hsd/specs/SPECS_2011.pdf, pp.175.

8. BENTHIC HABITATS AND ECOLOGICAL PROCESSES

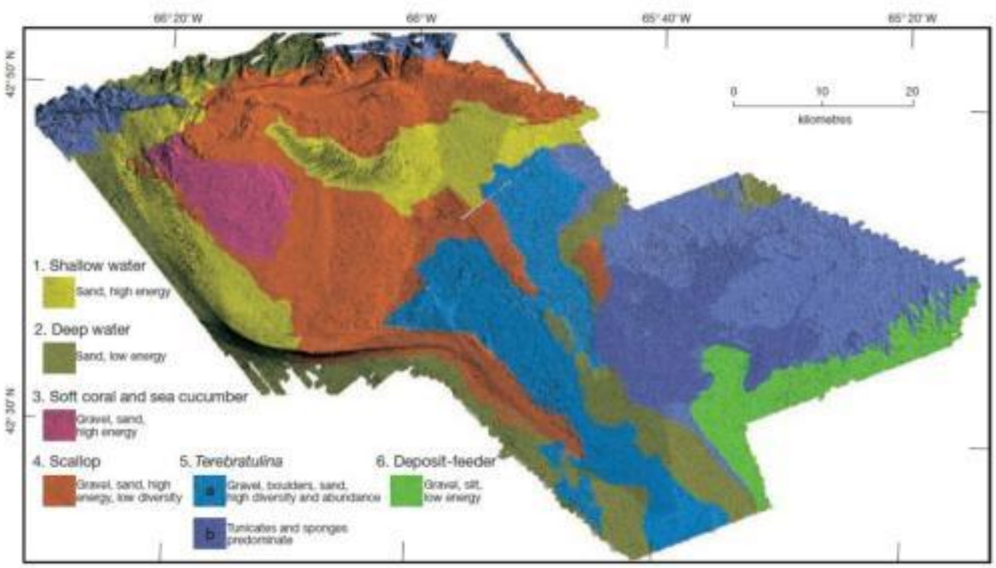
OVERVIEW:

- Maps depicting sea floor habitats and their ecological communities are critical for many environmental management, conservation, and research activities, and for the growing focus on coastal and marine spatial planning. Such maps depict either separately or in combination the spatial distribution and extent of benthic habitats classified based on physical, geological, geomorphological, and biological attributes and the benthic communities that reside in the mapped habitats. Additionally, maps can be produced that depict ecological processes across the sea floor.
- Although system-wide maps of benthic environments exist for Long Island Sound (and the pilot study area), these primarily depict geological attributes. Present ecological characterization of LIS benthic habitats and communities is based on data collected primarily prior to 1990, although some detailed seafloor mapping based ecological studies (including the pilot area) have been done since 1995. As such there remain significant data gaps relative to that which is needed for comprehensive sea floor habitat mapping and ecological characterization in the pilot area and in LIS overall.
- Within the scope of the LIS sea floor mapping pilot study, several benthic habitat and ecological characterization maps sets will be produced. The process will comprise several steps:
  - A preliminary classification of habitats using an initial interpretation of sea floor habitat maps based on acoustic data (bathymetry and backscatter); the classification scheme developed by Auster et al. (2009) for LIS will be used as the initial framework for habitat classification, and assessed and modified as appropriate during the pilot project in an adaptive manner to establish a classification scheme that can be applied to the LIS overall.
  - Based on the initial classification, the field sampling program will be designed to ground-truth the sea floor habitats and to collect geological and ecological data to provide data for complete habitat classification and ecological characterization; this sampling will be conducted using video, photographic and benthic grab sampling methodologies.
  - Once the geological and ecological data is analyzed, GIS-based benthic and ecological characterization maps will be developed:
    - the benthic habitat map set will comprise maps that show an overall classification of the habitat identified in the pilot area based on a final version of the LIS benthic habitat classification scheme; it will also include maps that depict particular characteristics of the habitats (e.g. diversity of habitat contributing features),
    - the ecological characterization maps will depict epibenthic and infaunal community types (based on multivariate statistical analyses) and their characteristics (e.g. biodiversity) found in the habitats mapped via the classification portion of this work.
- In addition to the GIS map products and associated GIS data files produced via the work outlined above, full documentation will be provided regarding the development and criteria used for the habitat mapping/classification scheme, and for the analyses and mapping integration procedures for the ecological data collected. Maps and associated data files will also be produced showing the locations of all field sampling sites.
- Based on the overall results of this portion of the pilot focusing on the development and production of benthic habitat and ecological characterization maps, a detailed set of

recommendations will be provided to help guide the application of the approaches / protocols developed to the rest of Long Island Sound.

8.1. Importance and Need

Sea floor landscape maps depicting the benthic habitat structure and ecological characteristics associated with those habitats are perhaps the most critical pieces of information that can guide the management and conservation of benthic environments. They typically integrate information from a variety of sources including acoustic maps (bathymetry and backscatter), sedimentary and geochemical data, and data from sediment samples and video/photography used to collect biological data and to supplement geological data collection (e.g. video records can show small scale geomorphic structures on the seabed). These data sources can then be collectively used to derive a series of maps that show the distribution of habitats, as guided by a habitat classification scheme, and their ecological characteristics (e.g. dominant fauna and flora, community structure, keystone species, biodiversity). Examples of habitat / ecological characterization maps are shown in Figure 8.1.



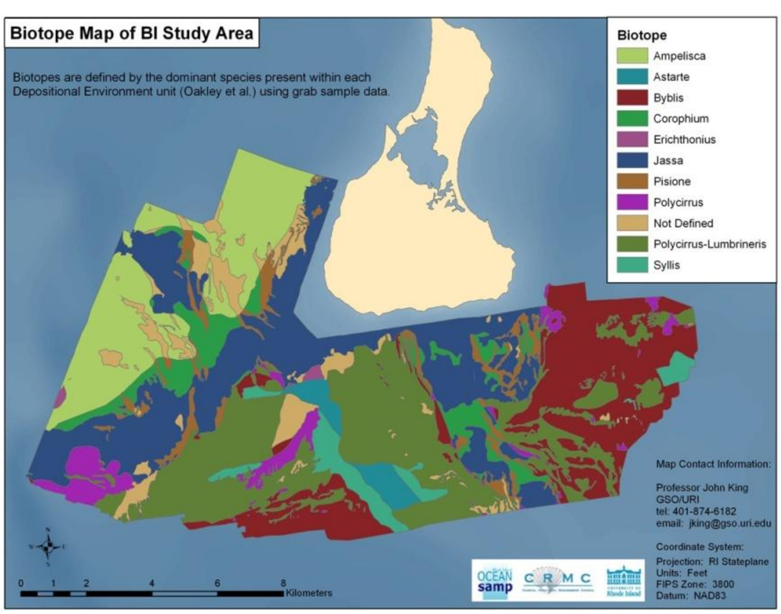
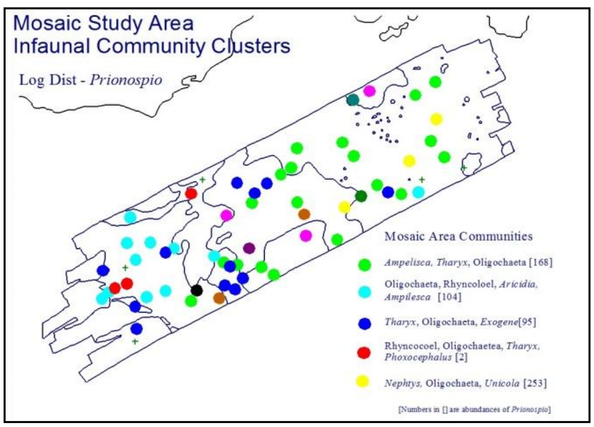


Figure 8.1: Examples of habitat/ ecological characterization (biotope) maps. Top: Browns Bank on Scotian shelf (Kostylev et al. 2001); Bottom: Rhode Island / Block Island Sound (King et al. URI)

Habitat maps show the geospatial distribution and extent of multi-scale sea floor patches (or elements) as determined via analysis and interpretation of acoustic mapping and associated geologic data (e.g. sediment grain size) and the physical and biological structural features that create benthic habitats within these patches. Such habitat maps can then be coupled with data (and related analyses) on epibenthic and infaunal communities to generate maps (referred by some as biotope maps) characterizing ecological communities and associated features (e.g. biodiversity), and showing their spatial variation relative to habitat distribution and composition (Figures 8.1 & 8.2). Benthic habitat and ecological characterization maps provide critical information about the extent and composition of marine resources, and are vital for communicating information about the distribution and abundance of species to resource managers, scientists and the public. These types of maps support landscape ecology and habitat connectivity studies that focus on understanding the dynamics of benthic communities, and are an important tool for ecosystem based management, including the process of coastal and marine spatial planning, as well as the design and evaluation of marine protected areas (MPAs) (Figure 8.3).



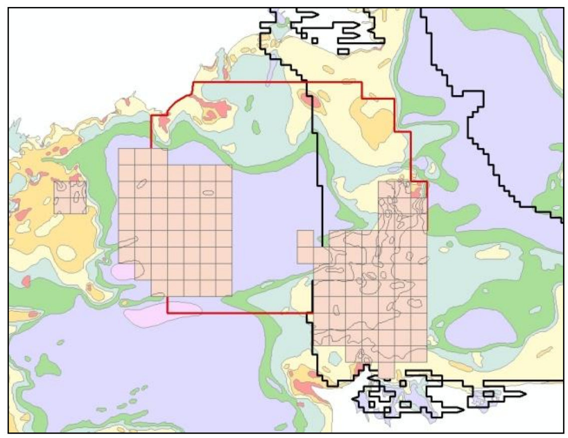
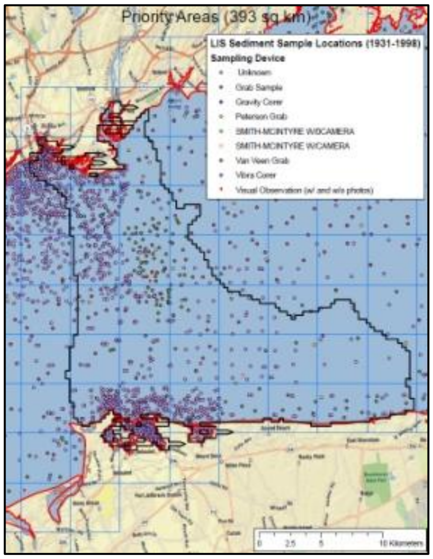


Figure 8.2 (left): Map showing distribution and variation of benthic communities in habitats defined based on acoustic mapping and sediment sampling south of the Thames River in Long Island Sound (note variation in community types within defined habitats (Zajac et al. 2000 & 2003).
Figure 8.3 (right): Map showing locations of modeled marine protected areas (red boundary and grids) based on sediment characteristics as habitat proxy (the LIS sediment texture map developed by Poppe et al. 2000) sediment sample locations in the pilot area in Long Island Sound (Neely and Zajac 2008, Zajac and Luk, 2011 and in preparation), illustrating how habitat maps are key to coastal and marine spatial planning. The black line is the boundary of the LIS mapping pilot project area.

8.2. Background and Existing Data

Maps describing the sedimentary environment, sediment thickness, surficial sediment and total organic carbon have been produced for the pilot area and for Long Island Sound (Figure 8.4). These maps have been developed from a combination of acoustic imagery and in situ sampling (Figure 8.5). To view these maps dynamically, please see the following URL:http://ccma.nos.noaa.gov/explorer/msp/lis/msp_lis.html.

There also exist ecological data (and in some cases related acoustic data) for the pilot area that can help guide the field data collection that will be needed for the production of habitat / ecological maps, augment any new data collected as appropriate and can provide the basis for assessing potential temporal changes in habitat and community characteristics. Benthic ecological studies in LIS have a history (see Zajac 1998 at the following URL: http://pubs.usgs.gov/of/1998/of98-502/chapt4/rz1cont.htm) going back to the mid 1950s, however collectively the studies are both spatially and temporally disjointed to various degrees. There were one-time surveys in the mid and late 1970's, providing data that helped establish



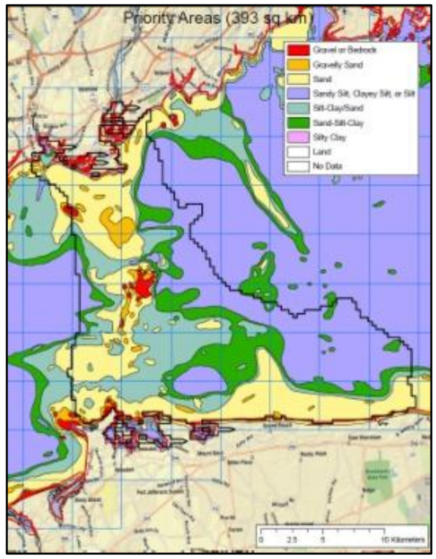


Figure 8.4 (left): Map of surficial sediment for the pilot area in Long Island Sound.

Figure 8.5 (right): Map of sediment sample locations in the pilot area in Long Island Sound.

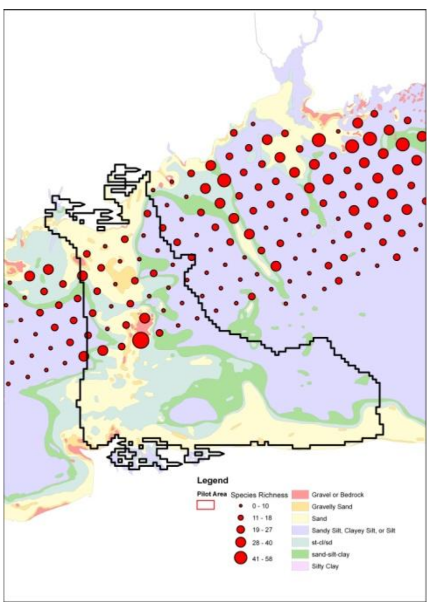


Figure 8.6 (above left): Spatial pattern of species richness across the northern portion of the pilot study area; data from Pellegrino and Hubbard (1983).

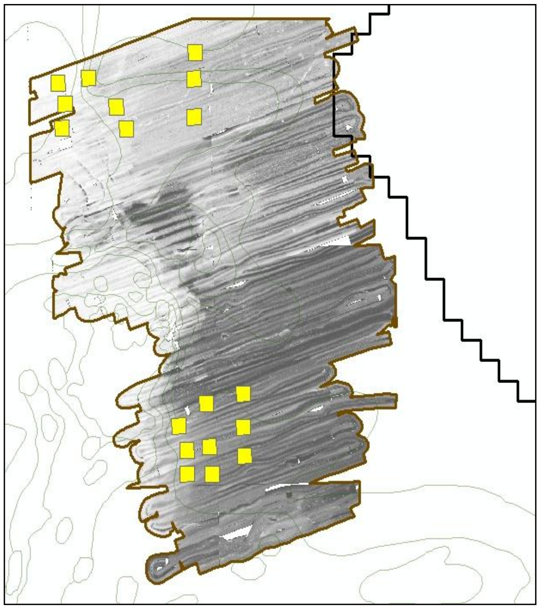
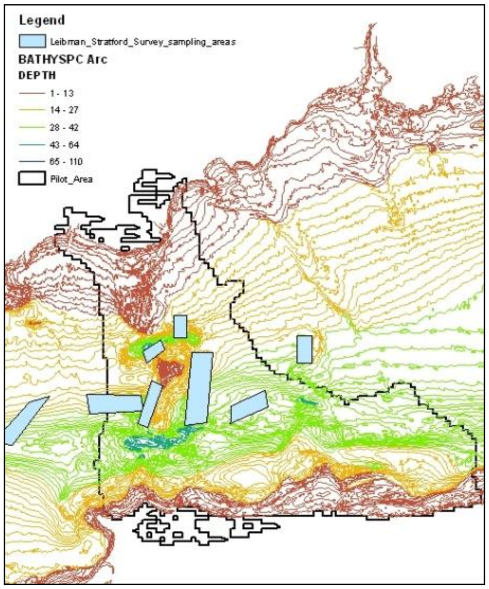


Figure 8.7: Side scan mosaic produced by Twichell et al. (1998) located on the eastern flank of the pilot study area; yellow boxes show areas sampled by Zajac (1998) for two years to look at seasonal and yearly changes in benthic community structure in relation to the various seafloor habitat elements found within the mosaic area.

trends in general community composition, diversity and relationships to habitat features (sediment type, depth, Figure 8.6). In some cases the spatial resolution was relatively coarse and in another survey the spatial resolution was high but only CT waters were sampled. In the early 1990s and then in the early 2000s a series of benthic samples were taken in LIS in support of the EPA EMAP and NCA programs, respectively. In addition to benthic community data, data on various pollutants were obtained, as well as toxicity tests performed using sediment samples collected in LIS. In the mid 1990s, Zajac (1998), in conjunction with USGS and the CT DEP, performed a demonstration project on how acoustic imagery/ sea floor mapping and conventional benthic sampling can be coupled to map habitats and understand benthic communities in LIS; one of the study sites was located in the LIS mapping pilot area (Figure 8.7).

One of the main findings of Zajac's (1998) study was that benthic community structure changes significantly relative to habitat structure both seasonally and yearly. Also, mesoscale habitat variation (on the order of 10's to 100's on m^2) is a significant source of community variation, in addition to the large-scale seafloor patch structure that is evident in the side scan mosaic shown in Figure 9.7. Details of the findings from this study can be found at: **http://www.lisrc.uconn.edu/DataCatalog/DocumentImages/pdf/Zajac_1998.pdf.** Most studies have focused on soft sediment communities. To date, there are no spatially comprehensive assessments of hard substratum community types or states in LIS, and only a limited effort to describe those communities in the pilot project area (Liebman 2007, Poppe – Roanoke Pt Shoal, Auster et al. 2009, Heupel and Auster in prep).

More recently, Liebman (2007) surveyed selected areas around Stratford Shoal (Figure 8.8) using side scan and ROV video. The survey documented critical epibenthic habitat features and communities that can be found in seafloor patches characterized primarily by coarse sediments, rocks, gravel and extensive boulder features. It also documented features that occur in patchy distributions on unconsolidated fine grained cohesive sediments such as lobster burrows. Here lobster burrows exhibited greater spatial scales of patchiness in steeper areas of cohesive sediments. If such patterns could be attributed to fine-scale variation in physical habitat attributes, it may be possible to predict where such aggregations occur and then develop planning tools to avoid such areas or minimize impacts when developing projects offshore.



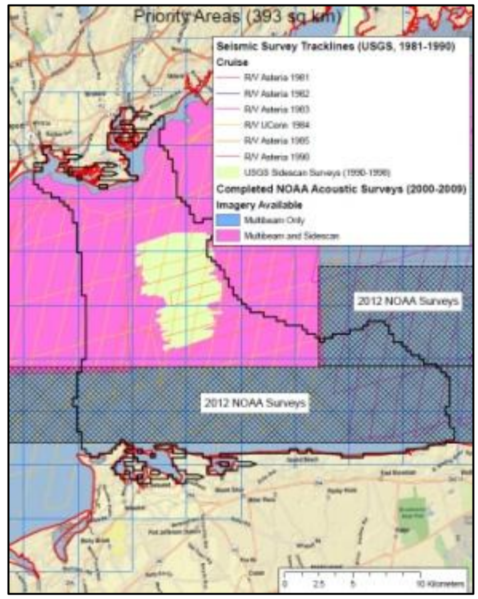


Figure 8.8 (left): Map showing the locations of acoustic and video surveys conducted by Liebman and colleagues in 2007).
Figure 8.9 (right): Map of surveyed areas in Long Island Sound. The maroon areas have been surveyed using acoustic sensors, the hatched areas have not.

8.3. Gap Analysis

8.3.1. Spatial and Temporal Coverage

While certain geologic and ecological characteristics have been mapped in LIS and the pilot area, there are data gaps that limit our ability to produce contemporary and spatially more comprehensive benthic habitat and ecological maps in the pilot area, and in the Sound as a whole. These data gaps are spatial, thematic and temporal in nature, and limit the utility of existing products for resource management applications. The spatial data gaps exist because acoustic imagery and ground validation (GV) and ecologoical data have not been collected in many portions of the pilot area, especially in waters shallower than approximately 10 m (Figure 8.9). Spatial data gaps also exist because historical information was analyzed at coarse spatial scales, which may limit its use for the breadth of management applications discussed at the August 2011 Spatial Prioritization workshop.

In addition to spatial gaps, there are also thematic and temporal data gaps because existing maps of the seafloor are primarily geologically based (surficial sediment types and sedimentary enviornments), and do not incorporate geomorphological, bathymetric, and, perhaps most critically, ecological components of habitat (e.g. mussel beds, oyster reefs, sponge communities, tube mats). There are also no maps that show the distribution and variation of both epibenthic and benthic infaunal communities within defined seafloor patches/habitats, except in some areas based on smaller scale studies (see above). In terms of temporal data gaps, many of the data collected that were used to produce geologically themed seafloor maps currently available, were collected over a time span approaching 80 - 100 years in the case of the surficial from sediment map, and close to 20 years for spatially coarse side scan data that was used in part to produce the sedimentary environment map.

Likewise, no significant ecological sampling of the benthos in Long Island Sound, either the epifaunal or infaunal components, nor in shallow or deep waters, over a large spatial scale has been done since the mid-1970s to early 1980s.

Additionally, current seafloor maps for Long Island Sound do not have clearly reported values of thematic accuracy. Understanding the thematic accuracy of a habitat map is important for managers because these accuracies provide guidance about a map's utility and limitations. Habitat maps with low thematic resolutions and unknown accuracies maybe acceptable for certain applications, but they are not representative of those commonly used in many scientific and management applications and may reduce the effectiveness of certain management actions (e.g., establishing no-take areas based on essential fish habitat) or inhibit the achievement of specific conservation goals (e.g., protecting a certain percentage of oyster reefs in a given area). Habitat maps with higher thematic resolutions and accuracies are more likely to be utilized for many different management applications because they contain added information that may be relevant and scalable to a wider array of issues in the marine environment. Furthermore, new management problems cannot always be anticipated (e.g., with respect to climate change), making extracting the maximum amount of information from acoustic imagery potentially important for being prepared to meet the future needs of the coastal and marine management community. Combined these spatial, thematic and temporal data gaps limit the applicability of existing map products for addressing resource management issues that are fine scale, occur in the southern part of the pilot area, and that are related to the biology and ecology of the Sound.

8.3.2. Suitability

Acoustic Imagery: Existing acoustic imagery will be suitable for producing preliminary products needed for field sampling design. The present proposal does include collection of additional data where in areas previously collected in order to increase data density to provide 100% bathymetry coverage. The necessity of this additional collection while be evaluated during the preliminary planning stage of the project.

Habitat Classification and Ecological Mapping: The classification schemes implemented for existing seafloor maps of LIS are geologically based and as such a benthic habitat classification scheme needs to be selected / developed that will provide the necessary framework for describing important habitat units based on information derived from acoustic, sediment and ecological data. In addition to a habitat classification scheme, a protocol will need to be developed for analyzing the biological community data and developing ecological characterization maps depicting the distribution of communities / biotopes / key species and biodiversity. The initial task in any habitat mapping effort should be to adopt or develop a classification scheme that clearly identifies and defines discrete habitat classes that are meaningful to the sea floor environment and ecology of the system being mapped. This scheme is subsequently used to guide the delineation and attribution of polygons during the mapping process. In the early stages of a habitat mapping project, and particularly within the context of a pilot project such as this, the development and application of a habitat classification scheme needs to adaptive so as to develop a scheme that best matches the environment being mapped and provides meaningful and consistent habitat descriptors / classifiers that can be used across the LIS system. Also, the classification scheme should be developed so that process driven habitat mapping / ecological characterization can be incorporated into the overall effort of mapping habitats, communities and processes and understanding seafloor ecology (Kostylev and Hannah 2007).

Recently, there has been a significant effort to develop a habitat classification scheme for LIS (Auster et al. 2009). This involved conducting a survey of potential users of map products to ascertain desired habitat attributes and their necessary resolution, linking survey data to the range of attribute types that can be integrated to habitat classification schemes, evaluating the utility of existing schemes, production of an integrated classification approach, and finally evaluating and modifying the draft scheme at a user workshop. The final classification scheme (Figure 8.10) is based on the linear and nested hierarchy of classes as in Greene et al. (1999). It is inclusive of all attributes identified in the user survey; eliminates redundant use of data at multiple scales (levels of hierarchy); uses enduring features as a foundation at higher levels; includes modifiers that are independent, parallel at class level, and linked to foundational attributes; and separates the types of classes by logical divisions based on the technological approaches used to collect data (that is, it insures completion of map coverages

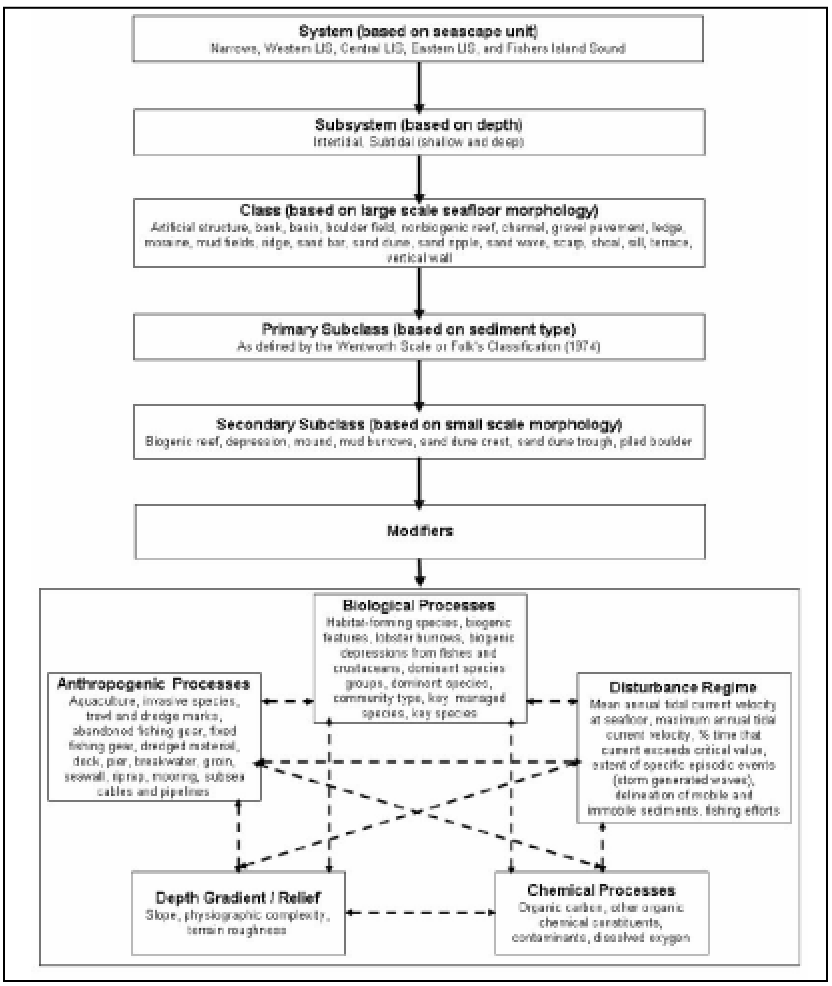


Figure 8.10: Habitat classification scheme developed by Auster et al. (2009) for LIS. Note some of the products are captured n other sections, e.g. depth gradient relief, chemical processes).

after limited field efforts). Implementation of this approach still will require a process to add and vet attributes and descriptors to insure unambiguous use.

Due to the extensive collaborative work among LIS managers, researchers and stakeholders in developing the classification approach shown in Figure 8.10, it is advisable to use this scheme as an initial framework for classifying habitats in LIS. The acoustic, GV and ecological data that will be collected as components of the pilot project will provide the necessary data for quantifying the various attributes / criteria / descriptors for the classification levels. These include, for example, geomorphological structure (Table 8.1), biological cover (Table 8.2), and morphological units (Table 8.3). As the pilot project evolves, the classification scheme and its components will be reviewed and assessed and changes made as needed, as a LIS habitat mapping classification scheme is developed for the pilot project, and by extension to the overall LIS mapping project. Assessments of the classification scheme will be made by the LIS mapping project partners in consultation with the LIS Mapping Steering Committee, with consultation as requested with others in the management community and other groups such as NGOs. The assessment will include, for example, 1) limitations of the source imagery and its integration with legacy imagery, (2) appropriate scale of delineation and minimum mapping unit (MMU), 3) capacity to extract habitat classes with a certain accuracy, 4) adequacy and amount of in situ information needed, and 5) how ecological information obtained from video / photo and sediment sampling is being incorporated into the habitat classification scheme for mapping habitats, and how the habitat maps and their data components are shaped into maps that depict more detailed ecological information that is critical for management and conservation.

The LIS classification scheme eventually developed via the pilot project should address the thematic data gaps present in existing seafloor maps. To implement this scheme, additional *in situ* data (i.e., underwater video and grab samples) will be needed to augment existing *in situ* data in order to map the geomorphological structure and biological cover habitat classes as well as for maps that characterize the ecological communities and processes that are present in the habitats identified. Ecological mapping leads to depictions of the spatial distribution and variation, and characteristics of benthic communities (epibenthic and infaunal) within the context of the seafloor habitat maps created (e.g. Figures 8.1 & 8.2; also see Kostylev et al. 2001, Brown et al. 2004). They also form the basis for the development of ecological process habitat maps which can address specific management and conservation issues (e.g. Kostylev and Hannah 2007). With respect to ecological mapping within the context of the pilot project, approaches taken in previous studies in LIS (e.g. Zajac 1998, Zajac et al. 2000, 2003) and surrounding waters (Cerrato et al. unpublished) that integrate acoustic mapping, field sampling and statistical analyses to assess and depict ecological characteristics within the context of seafloor landscape structure (as defined by the habitat patches), will provide a general framework for the production of ecological characterization maps and how biological data may be incorporate d with habitat maps. Briefly, field samples (video & grabs) are processed to extract data on ecological community composition, key species and to various extents the habitat forming species that are present in a particular seafloor patches. Analyses focus on determining community types, dominant species, and how differences in community structure and key species distributions are related to habitat characteristics (e.g. sediment grain size, rugosity, depth, biogenic structures). The analyses typically utilize multivariate approaches such as principal components analysis, canonical correspondence analysis, and redundancy analysis (e.g. Verfaillie et al. 2009 and above references). Once community types at each suitable location are identified, and the relationships that they exhibit to habitat and environmental variables, these can be incorporated into maps that integrate habitat and ecological communities, and/or show the spatial distribution of community types and key species among and within habitat patches.

[Note: The Nature Conservancy Long Island Sound Program has recently been developing a Long Island Sound Ecological Assessment (LISEA) project scheduled for completion October 2012. This effort uses existing data from various sources in a GIS overlay approach. Our efforts will take a different approach that is not ad hoc in terms of the data being collected and used (i.e. we are collecting targeted data, critical to habitat classification and ecological characterization), and incorporates well integrated analytical and statistical approaches used previously for other sea floor environments. Based on our present assessment of their map product, it is not amenable within our approach and as such will not be integrated into the products we will be developing. However, once the pilot project products described here are completed, comparison and assessment of their habitat maps relative to our products may be warranted.]

8.4. Required Data

The following contains a description of the type of data necessary to produce the products noted above.

8.4.1. Existing Data

Some legacy datasets (e.g., acoustic intensity) will need to be reprocessed before being used for habitat mapping. Other legacy datasets (e.g., bathymetry) also need to be reprocessed, and then evaluated to determine if additional bathymetry data will need to be collected in order to satisfy the density of coverage (i.e. 100% bathymetry coverage). In terms of ecological data, as noted above much of the pilot area has not been sampled with respect to obtaining ecological data, in those areas that have been extensively sampled data are from the mid-1990s. These data, and the associated analysis and results, will be very helpful in guiding the collection of new data within the pilot area. They can also be used to make comparisons in terms of potential long-term changes that may have occurred in this portion of LIS.

8.4.2. New Data

While benthic habitat mapping products, and the habitat classification schemes they may be based on, are not standardized, previous efforts by Auster et al. (2009) to develop a habitat classification system for LIS provide a starting framework. Other extensive work by NOAA Biogeography Branch conducting habitat mapping throughout the U.S. can provide effective context and guidelines. As noted above, the extensive experience working on mapping/ecological characterization projects in LIS and surrounding waters by members of the other partner groups (LISMaRC, LDEO), will also provide critical guidance in developing maps that depict habitats and ecological characteristics in the pilot area, and developing the protocols that lead to those maps.

8.4.2.1. Collection Methods

To increase the spatial and thematic resolution of benthic habitat and ecological characterization maps for the pilot area, new bathymetry and backscatter imagery should be collected covering 100% of the seafloor in areas were acoustic imagery is missing or legacy datasets are unusable. A suite of sensors should be used to collect this imagery, including multibeam echosounders (MBES), side scan (SSS) and interferometric SoNARs (PDBS). The most efficient acoustic sensor for mapping an area will depend primarily on the required products (i.e., bathymetry, backscatter or both), the survey depths and the maximum allowable vertical and horizontal uncertainty requirements (IHO 2008, NOAA 2011).

In addition to new acoustic imagery, GV and ecological data will also need to be collected to increase the spatial and thematic resolution and content of benthic habitat and ecological characterization maps for the pilot area. This field data should be acquired using a complimentary set of sampling equipment and techniques, including underwater video /photographic cameras and grab samplers. Underwater video would be preferred / required for certain habitat types, since it is non-destructive and provides an easily transferable and permanent record of information at a sample site. In some types of habitats, video / photographs may be the only way to get ecological data as grab sampling is not effective or impossible. In sedimentary areas, grabs (or cores) will be obtained using standard approaches depending on the sampling design and protocols developed based on initial interpretation and delineation of sea floor habitat patches from the acoustic imagery. Video data should also be obtained in sedimentary environments as it provides critical data on surficial structures and the distribution of other features that are not readily seem in acoustic imagery or within grab samples. Typically, benthic samples will be taken with a Van Veen grab (it would be beneficial to potentially obtain use of the USGS SeaBoss system with its photographic and video systems), samples will be washed on a 0.5 mm sieve to retain infauna and epifauna, and then processed to obtain data on species composition and abundances (biomass would also be an important characteristic to measure if time and funding permits). These data would then be analyzed as noted above and results incorporated into benthic and ecological characterization maps.

Manual and semi-automated methods may be used to develop habitat maps using the acoustic imagery and field geological and ecological data. Manual and semi-automated methods may be used to develop habitat maps using the acoustic imagery and field geological, physical and ecological data in the final product development stage of the project. It is anticipated that the acoustic data products will provide the base habitat characterization of the types and distribution of sea floor patches in the pilot area and also more detailed data on certain habitat attributes (e.g. rugosity). Habitat attribute data from other project components (see Figure 12.2), such as sediment erodibility and grain size (from Sediment-related project components), maximum summer temperature (from the Physical Environment project component) and habitat forming species distributions (from the Ecological characterization component) will then be integrated with the acoustic data / attributes to produce final habitat map products as guided by the classification scheme developed.

All of these mapping and sampling techniques are scalable to larger areas. However, less effort will be required to acquire acoustic data in deeper, more homogenous regions of the pilot area. Deeper, more homogenous areas require less effort because SoNARs are able to map larger areas in a single pass. The sampling density of geological and ecological (or GV) data will need to be determined once initial interpretations of the acoustic imagery are made and preliminary delineation of habitat patches (based on backscatter intensity, bathymetry and other features visible in these data). For ecological data there will be tradeoff between assessing spatial variation within a desired level of statistical accuracy at different spatial scales and coverage of samples across the pilot area, constrained by the total number of samples that can be taken and processed within the allowable budget. Zajac (1998) found that total abundance of dominant species and their individual abundances, and species richness, varied significantly both within and among patch types (habitats) delineated from a side scan sonar mosaic (Figure 8.7). These results will be useful in guiding the sampling density and apportionment of samples among different habitat elements. In terms of generating ecological characterization maps, several approaches can be taken which range from relatively simple mapping of community distributions and abundances of key species onto the habitat maps based on sample location (e.g. Figure 8.2), to more sophisticated spatial modeling of distributions using geostatistical techniques for example (e.g. Zajac 1996, can be viewed at http://www.lisrc.uconn.edu/DataCatalog/DocumentImages/pdf/Zajac_1999_2.pdf)

8.4.2.2. Existing Standards and Guidelines

NOAA has published existing standard operating procedures (SOPs) and specifications for collecting bathymetry and backscatter data. However, no uniform specifications and SOPs exist for the collection of GV data. Guidelines / specific protocols should be developed before geological and ecological data collection occurs in the pilot area, specifying at a minimum, recommended data formats, maximum allowable horizontal positional uncertainty and minimum number of sample site locations for a given area. Using an estimate based on previous benthic habitat mapping efforts completed by NOAA, on average, 4.2 GV points were needed per square kilometer for benthic habitat mapping. This estimate is based on work done in highly complex coral reef environments. Given that the pilot area is approximately 445 km^2, approximately 1,856 GV samples may be required to develop benthic habitat maps of this area, using this estimate. However, fewer geological and ecological field (GV) samples may be needed if existing *in situ* data are adequate for habitat mapping purposes and/or, at least for some habitat features such as sediment grain size, if benthic habitats appear homogenous for large portions of their delineated area. Zajac (1998) found that thee replicate grab samples was generally adequate to obtain an accurate estimate of local community variation in 200 m by 200 m sampling areas within different habitat types in the pilot area that appeared to be relatively homogenous based on acoustic imaging (Figure 8.7). It will also be important to assess how transitional areas among delineated habitats will be sampled. The areas have been shown to be potentially important ecologically due to increases in habitat diversity attributes and species diversity in LIS (Zajac et al. 2003).

8.5. Delivered Product(s)

The following contains a description of the type of product that will be provided.

8.5.1. Raw Product

Several raw products for the pilot area would be delivered at the conclusion of the pilot project. These raw products specifically include: (1) raw GPS data for the field geological and ecological sample site locations, (2) underwater video/photos for each site and a database characterizing the features at each site based on information in the video, (3) a habitat classification scheme that will be applicable to other portions of LIS, and 4) a data base containing the species identifications and abundances from all the field sample sites where ecological data are collected. Raw acoustic datasets collected and described in other product sections (e.g. acoustic intensity, bathymetry) will also be provided.

8.5.2. Interpreted Product

8.5.2.1. Geospatial imagery and shapefile products

Several processed and interpreted products will be delivered at the conclusion of the pilot project. These products specifically include: (1) shapefile of the differentially post processed GPS data for the GV and ecological sample sites, (2) site community characterizations based on underwater video for each filed sampling site, with sites classified based on community composition from multivariate analyses (point shapefile with appropriate ecological attribute fields) 3) site community characterizations based on benthic grab samples with sites classified based on community composition determined from multivariate analyses (point shapefile with appropriate ecological attribute fields), 4) benthic habitat map shapefile classified using the LIS classification scheme that will be developed as part of this pilot project. Benthic habitats will be delineated from the acoustic imagery, and characterized using *in situ* ground validation data. Two standards will be important for guiding this mapping process, i.e., the application of a uniform delineation scale and MMU. MMU describes the smallest polygon or feature delineated during the digitization process. The delineation scale describes the scale at which habitat features are digitized from the acoustic imagery. The appropriate scale of delineation and MMU size depend on: (1) the needs of the management community, (2) the spatial resolution of the source imagery, (3) the ability to delineate features reliably from this imagery, and (4) the level of effort dedicated to map production. Habitat maps with different delineation scales and/or MMUs maybe developed for different parts of LIS, depending on the depth and heterogeneity of the environment. Shallower (<40 m) and/or more heterogeneous environments should be mapped at finer scales of delineation (i.e., 1:1,000) and smaller MMUs (100 m^2) in order to adequately capture geologic and biologic characteristics and processes important for ecosystem-based management. Coarser scales of delineation (i.e., 1:4,000) and/or larger MMUs (1,000 m^2) might be used in deeper (>40 m) and/or more homogenous environments in the Sound, unless otherwise specified/determined. It is also important to note that the scale of delineation and size of the MMU will largely dictate the habitat mapping technique that is used. Manual delineation and attribution methods may be adequate for small geographic areas with coarse delineation scales and MMUs, but too time consuming to use to map large geographic areas with fine delineation scales and MMUs. Semi-automated methods (e.g. ENVI feature extraction) should be used in these situations at a minimum to reduce the time (and cost, potentially) of habitat map development. See the section 8.6 for the estimated time needed to map the pilot area using manual and semi-automated techniques, respectively. Another consideration that will need to be addressed is the integration of data that essentially have a small spatial extent (e.g. a grab sample) and how these are related to MMUs determined appropriate for the project area.

8.5.2.2. Geospatial map Products

Digital cartographic plots (in GeoPDF format) will be produced depicting benthic habitats and the ecological characteristics of those habitats in the pilot area, including the geographic zone, geomorphological structure and biological cover/habitat attributes of the seafloor, and benthic communities and other ecological characteristics (e.g. biodiversity) within the delineated habitats. Maps of the source imagery and GV /ecological sample locations will also be produced. These maps will be properly attributed with standard cartographic elements and data source references.

8.5.3. Reports and Documentation

In addition to the raw and interpreted data, additional descriptive documentation will be delivered at the conclusion of the pilot project. This documentation will include a report describing the methods used, summarizing the key results and project findings as well as discussing potential uses of the products listed above. The reports will also include a full description of the analyses of the ecological data on which the components of the habitat maps and the ecological characterization maps are based. Metadata for all GIS products produced during this project will be delivered along with the report. This metadata will be prepared in an FGDC-compliant format in accordance with Federal Executive Order 12906. See the data management, Section 4.1 - Metadata of this report for more details about metadata development and standards.

8.6. Cost and Time Estimates

The cost of developing benthic habitat and ecological characterization maps for the pilot area will depend on the mapping approach that is taken, particularly for the initial delineation of habitats based on the acoustic data. It will most likely take longer and cost more if habitat maps are produced using manual heads-up digitizing and attribution versus using a more semi-automated approach. Preliminary estimates, based on habitat mapping of coral reef environments, suggest that a person using a manual approach can map and characterize approximately 0.09 km^2 per hour, whereas they can map and characterize approximately 0.75 km^2 per hour using a semi-automated approach (Costa et al. 2009). While these numbers are preliminary, they suggest that a semi-automated approach may be able to map about 0.66 km^2 more area per hour than a manual digitization and classification approach. Using these estimated rates of mapping, it would take approximately 4,945 hours (~7 months) to develop a benthic habitat map for the pilot area using a manual approach. If semi-automated methods was used, it would take approximately 2,474 hours (3 ½ months) to develop a benthic habitat map for the same area, assuming that the estimate given above holds for the types of habitats and features that are present in the pilot area.

It is important to note that these estimated numbers only include the time needed to delineate and attribute habitat features in the imagery. They do not include the time required for acoustic data acquisition, acoustic data processing, GV field work, and GV data processing, as well as report and product generation. The time needed to acquire versus process imagery is approximately a 1:3 ratio (based on estimates developed by the NOAA office working in coral reef of habitats). For example, if 1 month is spent acquiring acoustic data, an additional 3 months will be required to process it and produce an image that is ready to be interpreted. A similar time ratio (1:3) is required for the acquisition and processing of GV data (i.e., 1 month of GV data collection will require approximately 3 months to process it). If an underwater drop camera is used to acquire certain GV data, approximately 50 to 60 GV sites can be occupied per day. Based on the GV calculations in section 8.4.2.2., it would take approximately 1 month to acquire the 1,856 GV samples needed to map the pilot area and approximately 3 to 3 ½ months to process the GV data and format it in a way that is useful for habitat mapping. All told, it would take anywhere from 7 months to 11 ½ months to acquire and process the GV data and to develop a benthic habitat map (Table 8.4).

Task	Estimated # Months
Acoustic Data	
New Acquisition	-
Processing/ Reprocessing	-
Ground Validation Data	
Acquisition	1
Processing	3 – 3 ½
Habitat Delineation & Attribution (1 or the other)	
Manual	7
Semi-Automated	3 ½
Total	7 ½ – 11 ½

Table 8.4: Estimated time needed to: (1) acquire GV data, (2) process GV data and (3) develop a benthic habitat map.

Based on work conducted by Zajac et al. 1998 in the pilot area, about 50 – 55 benthic grab samples can be collected and ship processed per day over the ~55 km^2 study area shown in Figure 8.7. Laboratory post-processing took approximately 3 months to get to the analysis phase.

8.7. References

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Table 8.1: Table denoting potential geomorphological structure classification attributes for the pilot area in Long Island Sound.

Geomorphological Structure	Geomorphological Structure refers to a feature's dominant physical composition. Structure types are defined in a collapsible hierarchy ranging from major to detailed classes.		Describes geomorphological structure class at finer spatial/thematic scale (Shepard, 1973)	**Percent Hardbottom**	Percent Hardbottom refers to the amount (i.e. patchiness) of hardbottom habitat within a habitat polygon.
Major Class Name	**Detailed Class Name**	**Definition**	**Modifier**	**Class Name**	**Definition**
Hardbottom (Hard)	Aggregate Reef	Continuous, high-relief and highly rugose reefs of variable shapes oriented parallel to the shoreline. Maybe biogenic or non-biogenic.		0% ≤ 10%	Harbottom is estimated to cover 0%≤10% of a habitat polygon.
	Aggregated Boulders	Clustered boulders that cover ≥10% of the entire polygon, but are too small (less than the MMU) or are too close together to map individually.		10% ≤ 30%	Harbottom is estimated to cover 10%≤30% of a habitat polyon.
	Bedrock	Native unconsolidated rock underlying the surface of the seafloor.		30% ≤ 50%	Harbottom is estimated to cover 30%≤50% of a habitat polyon.
	Gravel	Areas where ≥10% of the entire polygon is covered by coarse sediment with particle sizes > 2 and <256 mm (Wentworth, 1922).	cobble, pebbles, stones	50% ≤ 70%	Harbottom is estimated to cover 50%≤70% of a habitat polyon.
	Individual Boulder	Areas where ≥10% of the entire polygon is covered by individual boulders with diameters > 0.25 m (Wentworth, 1922).		70% ≤ 90%	Harbottom is estimated to cover 70%≤90% of a habitat polyon.
	Mixed Hard Sediments	Areas where ≥10% of the entire polygon is covered by any one sediment type (i.e., cobble, pebble, mud and sand) based on Wentworth, 1922 classificaitons.		90% - 100%	Harbottom is estimated to cover90% - 100% of a habitat polyon.
	Shell	Areas where ≥10% of the entire polygon is covered by bivalve shells.		Unclassified	An estimate of percent hardbottom is not appropriate for this particular major biological cover class.
Unconsolidated Sediment (Soft)	Mud	Areas where ≥10% of the entire polygon is covered by fine sediment with particle sizes range from 1/256 - 1/16 mm (Wentworth, 1922).	Clay, Sandy Clay, Silty Clay, Silt, Clayey Silt, Sandy Silt	Unknown	Habitats that are indistinguishable in the acoustic imagery due to noise in the bathymetry and/or backscatter or other interference with the acoustic signature of the seafloor.
	Mixed Soft Sediments	Areas where ≥10% of the entire polygon is covered by equal parts sand, silt and clay as defined by the Shepard classificaiton system	Sand, Silt, Clay		
	Sand	Areas where ≥10% of the entire polygon is covered by coarse sediment with particle sizes range from 1/16–1 mm (Wentworth, 1922).	Sand, Clayey Sand, Silty Sand		
	Unconsolidated Sediment with Scattered Rock/Boulder	Areas covered by uncondolidated sediment and <10% of the entire polygon is covered by scattered rocks or isolated boulders that are too small (< MMU) to be delineated individually.			
Other Delineations	Artificial	Man-made habitats such as submerged cables, pipelines, wrecks, large piers, submerged portions of rip-rap jetties, the shoreline of islands created from dredge spoil, shipwrecks, and marine debris (derelcit fishing gear).	Explicit identification of feature as captures under definition.		
	Land	Terrestrial features at or above the spring high tide line as denoted by the wrack line.			
Unknown	Unknown	Habitats that are indistinguishable in the acoustic imagery due to noise in the bathymetry and/or backscatter or other interference with the acoustic signature of the seafloor.			

Table 8.2: Table denoting potential biological cover classification attributes for the pilot area in Long Island Sound.

Biological Cover	Biological cover denotes the dominant biological component colonizing the surface of the feature.	**Percent Major Cover**	Modifiers describing patchiness of dominant biological cover with a polygon
Class Name	**Definition**	**Class Name**	**Definition**
Algae	Polygons (with >10% of their area) dominated by any combination of numerous species of algae. May be turf, fleshy, filamentous etc.	10% ≤ 50%	Discontinuous biological cover with breaks in coverage that are too small to be mapped as a different feature (*i.e.* , smaller than the MMU). Overall cover of the major biological type is estimated at 10%≤50% of the polygon.
Bivalves	Polygons (with >10% of their area) dominated by live bivalves and bivalve shells.	50% ≤ 90%	Discontinuous biological cover with breaks in coverage that are too small to be mapped as a different feature (i.e., smaller than the MMU). Overall cover of the major biological type is estimated at 50%≤90% of the polygon.
Live Coral	Polygons (with >10% of their area) dominated by live corals (e.g., northern star coral) and other organisms	90% ≤ 100%	Major biological cover type covering >90% of the polygon. May include areas of biological cover that are too small to be mapped independently (*i.e.* , smaller than the MMU).
No Cover	Polygons covered by <10% of any of the other biological cover types. Overall, *No Cover* is estimated at 90%-100% of the bottom with the possibility of some very low density biological cover.	Unclassified	An estimate of percent cover is not appropriate for this particular major biological cover class.
Seagrass	Polygons (with >10% of their area) dominated by any single species of seagrass (*e.g.* , Eelgrass) or a combination of seagrass species.	Unknown	Habitats that are indistinguishable in the acoustic imagery due to noise in the bathymetry and/or backscatter or other interference with the acoustic signature of the seafloor.
Sponges	Polygons (with >10% of their area) dominated by any single species of sponge (*e.g.* , finger sponge) or a combination of sponge species.		
Unknown	Habitats that are indistinguishable in the acoustic imagery due to noise in the bathymetry and/or backscatter or other interference with the acoustic signature of the seafloor.		

Table 8.3: Table denoting potential morphological unit classification attributes for the pilot area in Long Island Sound.

Morphological Unit	Zone refers to each benthic community's geographic location. It does not address a polygon's substrate or biological cover types.
Class Name	**Definition**
Basin	A broad area that is sunk below the surrounding seafloor.
Bank	A broad elevation of the sea floor around which the water is relatively shallow.
Escarpment	A long steep slope or cliff at the edge of a plateau or ridge; usually formed by erosion or the faulting of the earth's crust.
Channel	Naturally occurring channels that often cut across several other zones.
Dredged	Area in which natural geomorphology is disrupted or altered by excavation or dredging.
Dredged material	Area in which deposited sediments were excavated from other areas.
Land	Terrestrial features at or above the spring high tide line as denoted by the wrack line.
Ridge	A long, narrow elevation on the sea floor.
Shoreline Intertidal	Area between the spring high tide line (or landward edge of emergent vegetation when present) and lowest spring tide level.
Vertical Wall	Area with near-vertical slope from shore to shelf or shelf escarpment.
Unknown	Habitats that are indistinguishable in the acoustic imagery due to noise in the bathymetry and/or backscatter or other interference with the acoustic signature of the seafloor.

9. SEDIMENT TEXTURE AND GRAIN SIZE DISTRIBUTION

9.1. Importance and Need

Sediment texture or grain size composition is an essential element of any habitat classification. Gravel, sand, mud and various mixtures of these major grain size classes provide very different habitats. Besides its importance for habitats the surface sediment classification is a key element for managing different resources in LIS. In fact, different bottom types can be resources by themselves (e.g. sand).

While acoustic data, especially multibeam and sidescan backscatter, can provide information on different grain size composition of the seafloor (coarse sediments usually correspond to high backscatter and finer sediments are smoother and thus correspond to lower backscatter) this information does not contain enough details on the composition to discriminate some benthic habitats. In some cases, (e.g. in mud-dominated areas) differences in the backscatter can be caused by fine-scale morphology rather than by differences in grain size content (Nitsche et al., 2004; Ferrini and Flood, 2006). Therefore sediment grain size distribution requires analysis of actual samples and the sampling should be guided by acoustic data.

In addition to grain size information the total organic content distribution would be of great value for the biological habitat classification since it can be an indicator of biological activity. Basic organic content data can be easily extracted from the same samples as the grain size data and a comparable resolution would be desirable.

Because of its importance for habitat classification, the sediment texture needs to be mapped for the entire study area at a scale and resolution of the habitat sizes of interest.

9.2. Background and Existing Data

Based on a series of sediment grab samples and sediment cores USGS has produced a sediment texture map for the entire LIS (Figure 9.1; Poppe et al., 2000).

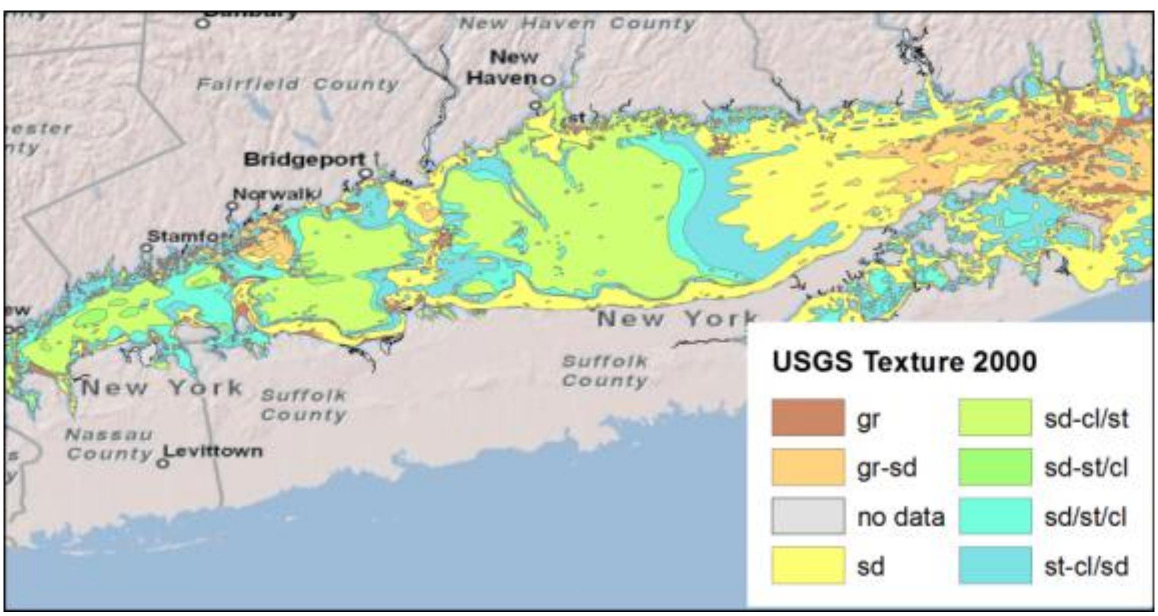

Figure 9.1 - USGS grain size map of LIS from 2000 (Poppe et al., 2000).

This compilation is based on a large number of grain size data in combination with a limited amount sidescan data where those were available (Poppe et al., 2000). The grain size sample information is compiled in the two USGS databases: The LIS Surficial Sediment Data counts >14,000 entries between 1930 and 1998 with a majority ~10,000 from the 1930s (Figure 9.2). The east coast sediment texture database contains ~2420 entries for LIS between 1980 and 2010. The large majority of these data are from sediment grabs and few are from sediment cores and images sources.

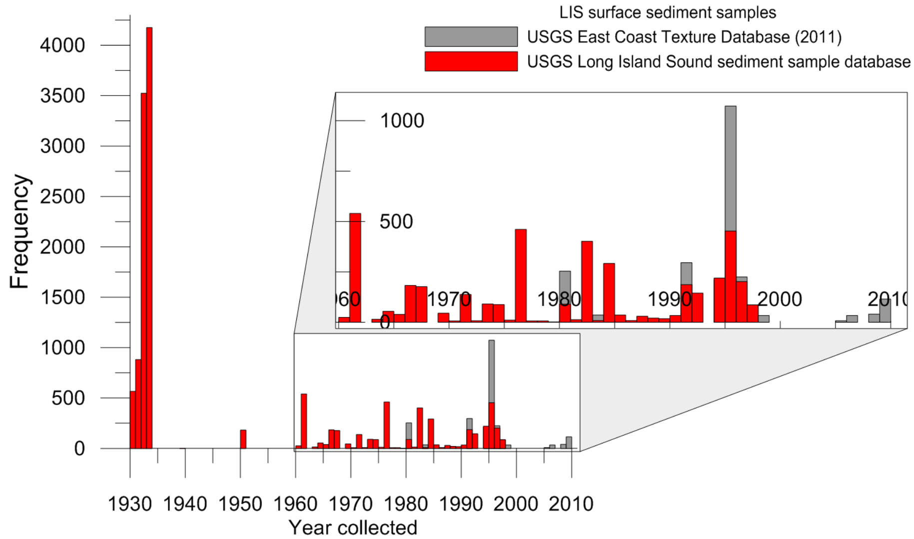

Figure 9.2 - Number of existing sediment texture data from various databases by year.

A detailed view of the pilot study area shows that only few sediment cores exist in the area and that a set of newer sediment grabs have been collected for the interpretation of the sidescan sonar data in the center of the sound (Figure 9.3).

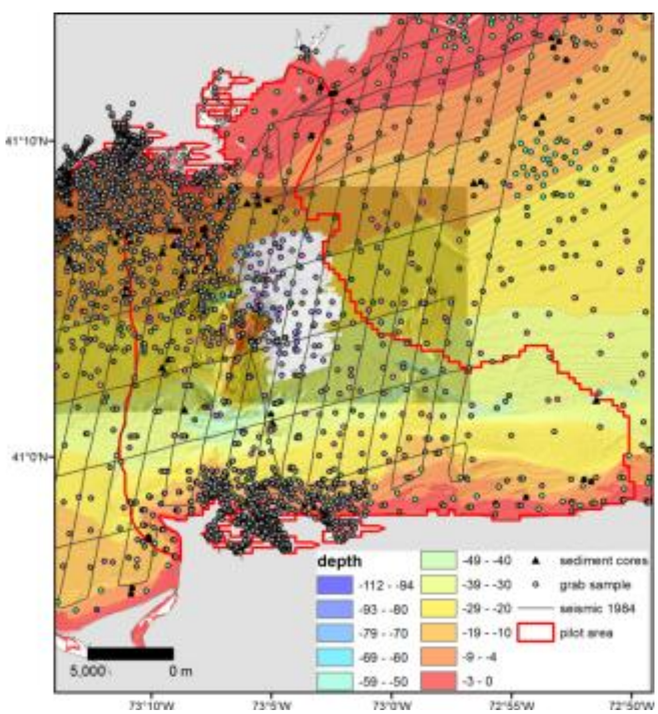

Figure 9.3 - Distribution of existing sediment samples and subbottom seismic lines in the designated pilot area. Sediment cores are shown as triangles (black and green indicate different data sources). Circles show locations of sediment grab samples of different databases. Note that grey circles indicate old (1930s) samples. Also note the number of newer (1990s) samples in the sidescan survey area in the center of the sound.

9.3. Gap Analysis

9.3.1. Spatial and Temporal Coverage

While some detailed sediment texture maps exists for small parts of LIS, the existing LIS-wide interpretation does not have the required resolution for the detailed habitat maps envisioned by this project. Full coverage of bathymetry and backscatter data will allow a more precise and detailed mapping of the boundaries and extent of sediment texture. Since grain size is the basis for many derived habitat products it needs to reflect the environment as accurately as possible. As demonstrated for sediment environments (sect. 10.3) a new interpretation of sediment texture based on higher resolution data will result in significant differences on the local level. Some of the existing sidescan in the pilot area might be sufficient (e.g. the USGS survey for 1999, Figure 9.3) for guiding the analysis of sediment texture. It should be part of this pilot study to investigate to which extent these existing data can be integrated and used for the LIS mapping project.

It is unclear to what extent most of the older sediment samples from the 1930s reflect the present condition and if their grain size classification follows the present standards. Samples from the 1930s to 1990s and might not represent any changes of the LIS bottom environments during and after this period On the other hand, grain size data from the 1990s and 2000s might still represent current conditions in some areas that have not changed much. However, the description of biological habitats requires an accurate description of the substrate texture and we cannot be sure beforehand, if the older data still reflect the present state. Therefore the pilot study should include a detailed comparison of previous and the new sediment texture interpretation as well as an analysis of the validity of older grain size samples to evaluate to what degree older sediment samples could be reused/incorporated in the new mapping study.

9.3.2. Suitability

Even in the case that many of the more recent (10-15 years old) data can be used for this study, the density of existing data is not sufficient in many parts of the LIS and the study area. Sufficient data might only be available for the central part of the pilot area.

9.4. Required Data

To produce the sediment texture / grain size and total organic content distribution requires the following data sets:
(1) grain size analysis from sediment grabs
(2) acoustic backscatter mosaics (from multibeam or sidescan sonar)
(3) total organic content from sediment grabs

9.4.1. Existing Data

Backscatter data, mostly form sidescan sonar, exists for patches of the LIS as well as for parts of the pilot study area (s. acoustic data, backscatter data) for details.

The figures above also show the distribution of existing data in the pilot. While some of the newer data could probably be used to generate these products, especially in the central area with newer sidescan data, many of the older 1930s sediment data might not reflect the present seafloor texture.

9.4.2. New Data

For this project we envision to use an updated backscatter mosaic of the entire study area that might include new and old data (s. section acoustic products for details).

Additional sediment grain size information should be collected using sediment grabs. The sample locations should be determined based on the backscatter mosaic. Areas where backscatter data suggest high variability of bottom texture need to be sampled more densely, areas that appear more uniform can be sampled with less density. Some additional samples should be taken in areas where previous samples exist to verify that they represent current conditions.

In case that acoustic backscatter information is not available in time to plan the sampling, grain size samples could be taken following a regular grid or using current knowledge of expected distribution of different bottom environment. However, this approach has the strong risk that critical areas with high variability are not covered adequately and additional sampling might be required to fill critical gaps. Thus is should be preferred to plan the sampling using acoustic data.

Sediment samples can be obtained by a dedicated survey, but might also be collected as part of the biological data collection effort. In fact, it is probably desirable to have co-located samples for grain size data and biological assessment so future analysis can rely on the sediment data representing accurately the location of the biological sample.

Grain size analysis can be done on subsamples of sediment grabs or core tops. The analysis should follow established protocols comparable to USGS open-file report 00-358 (Poppe and Polloni, 2000), which would be adequate for this study. Weight percentages for individual phi classes should be determined and then summarized into percentages of clay, silt, silt and clay (mud), sand, and gravel following the Wentworth classification (Wentworth, 1922; Figure 9.4).

Millimeters (mm)		Micrometers (µm)	Phi (ϕ)	Wentworth size class	
	4096		-12.0	Boulder	Gravel
	256		-8.0	Cobble	
	64		-6.0	Pebble	
	4		-2.0	Granule	
	2.00		-1.0	Very coarse sand	Sand
	1.00		0.0	Coarse sand	
1/2	0.50	500	1.0	Medium sand	
1/4	0.25	250	2.0	Fine sand	
1/8	0.125	125	3.0	Very fine sand	
1/16	0.0625	63	4.0	Coarse silt	Silt
1/32	0.031	31	5.0	Medium silt	
1/64	0.0156	15.6	6.0	Fine silt	
1/128	0.0078	7.8	7.0	Very fine silt	
1/256	0.0039	3.9	8.0	Clay	Mud
	0.00006	0.06	14.0		

Figure 9.4: Sediment grain size classes and related phi grades after Wentworth (1922).

Classification Scheme/procedure:

Based on the results of the grain size analysis the samples should be classified using a modified version of Shepard's (1954) ternary classification system shown in Figure 9.5 (Shepard, 1954; Schlee, 1973). This classification scheme should also provide usable information for determining biological habitat classes. In case that requires less distinction some of the sediment texture classes can be combined into fewer ones. However, steps should be taken to ensure that these classification coherent.

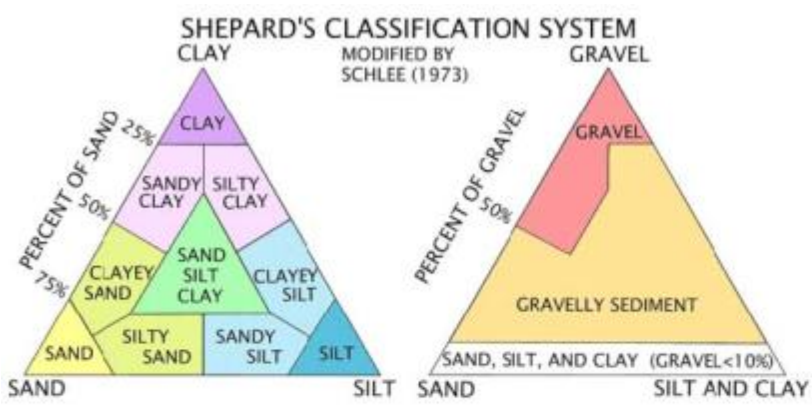

Figure 9.5: modified classification scheme for grain size sediments (Poppe and Polloni, 2000).

The classified grain size data should be overlain onto backscatter data to distinguish sediment texture classes in the backscatter data. Based on a combination of these two data sets the study area can be classified into the different classes. This can be done manually or semi-automated using supervised classification schemes.

Additional bottom photographs, which might be taken for ground verification for other products, could be used for verification of bottom types and might provide a good QC mechanism but are not essential for generating a texture map. This might be especially useful to verify hard bottom types and bedrock outcrops at locations where sediment grabs could not be obtained.

Total organic content
Total organic content can be measured on the same samples as for grain size analysis. The loss-of-ignition or equivalent method provides sufficient accuracy for the purpose of this project, while keeping costs low. Standard protocols as described by EPA guidelines should be followed.

9.5. Delivered Product(s)

The following contains a description of the type of product that will be provided.

9.5.1. Raw Product

Acoustic backscatter data products are described in the acoustic section of the statement of work.

Specific products for the grain size analysis include a table (Excel-format) describing GPS location, acquisition details including sampling device, and the results of the grain size analysis including weight percentages of the different Phi sizes as well as the total amount of clay, silt (mud), sand, and gravel. Another column will include percentage of total organic content.

9.5.2. Interpreted Product

9.5.2.1. Geospatial imagery and shapefile products

Several interpreted sediment texture GIS products will be delivered at the end of the project. These products are:
(1) a point shapefile of sample locations with grain size attributes that include the values of the data table described above.

(2) a shapefile with polygons outlining the different sediment texture classes following the sediment classification scheme above.

(3) a raster image files of the total organic content distribution in the pilot area.

Project of these shapefile will follow the general guidelines for geospatial products outlined in the data management section.

9.5.2.2. Geospatial map products

Digital maps in GeoPDF format will be produced depicting sediment texture/grain size and organic content distribution in the pilot area. Maps of sample locations will also be produced. These maps will be properly attributed with standard cartographic elements and data source references.

9.5.3. Reports and Documentation

In addition to the raw and interpreted data, additional descriptive documentation will be delivered at the conclusion of the pilot project. This documentation will include a report summarizing the key results; describing the methods used, data acquisition, processing, interpretation, and project findings, as well as discussing potential uses of the products listed above. Metadata for all GIS products produced during this project will be delivered along with the report. This metadata will be prepared in an FGDC-compliant format in accordance with Federal Executive Order 12906. See the data management section of this report for more details about metadata development and standards.

In addition, the report will include recommendation on the extent to which older grain size data can be included into main mapping project.

9.6. Cost and Time Estimates

We assume processed backscatter data are provided as part of other products, so we are not including those. For best results the sediment sampling program should be planned based on acoustic data, but usually preliminary backscatter images and DEMs are sufficient to identify key locations for the sampling program. Thus there is no need to wait until the final versions of these products are available.

The actual number of grain size samples need to characterize and verify acoustic data in the pilot study area will depend on the variability of the bottom shown in the backscatter data. For this estimate we assume that ~400-500 grain size samples/analyses will be necessary. Some of these will come from sediment cores (40-60) while the majority would be grab samples. Sample acquisition should be coordinated with other products, e.g. ground verification of benthic habitats to minimize efforts and costs and maximize synergies. With this dense cover an average of 40 stations is realistic which corresponds to 2-3 weeks of field work.

Processing these number of grain size samples will take about 4-5 months and interpreting the results and creating the final maps for the pilot area another ~2 months.

9.7. References

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10. SEDIMENTARY ENVIRONMENTS (PHYSICAL)

10.1. Importance and Background

Understanding the processes that transport, erode and deposit sediments is critical for understanding and defining benthic habitats. Sedimentation processes such as floods, currents, tides and storms can be better interpreted from the sea-floor morphology and sediment characteristics.

While sediment texture describes the grain size composition the sedimentary environment describes the processes dominating/controlling a certain location such as deposition or erosion. These processes are an important factor in identifying different habitats. Such information about sediments processes is also critical for understanding the dynamic of the seafloor in LIS and where identified habitats are likely to be changing or stable.

The sedimentary temporal and spatial record of these processes can be obtained from coupling multibeam bathymetry, subbottom, and sediment cores information. The multibeam bathymetry provides the large-scale morphology, dimensions and spatial distribution of bed forms. However, they do not provide any information on the thickness of surface sediment layers or the nature and thickness of subsurface sediments. Thus, what may appear as a sandy bottom in the sidescan record may in fact be only a thin layer of sand atop rock or some other sediment type. This distinction can have significant ramifications for those looking for exploitable sand and aggregate deposits or the potential for seabed erosion or disturbance. Subsurface information from subbottom data and sediment cores are necessary to clearly distinguish depositional and erosional areas or identify a thin layer of sediments covering bedrock outcrop. While subbottom data provide the spatial coverage necessary for mapping different environments sediment cores provide the temporal evolution and detail needed for the interpretation of the acoustic data.

10.2. Background and Existing Data

USGS has produced a LIS wide interpretation of sediment environments (Figure 10.1; Knebel et al., 1999; Knebel and Poppe, 2000). Like the sediment texture interpretation this interpretation was based on previously existing sidescan and seismic data as well as bottom samples and photographs. This classification distinguished deposition, erosion, sorting and transportation environments.

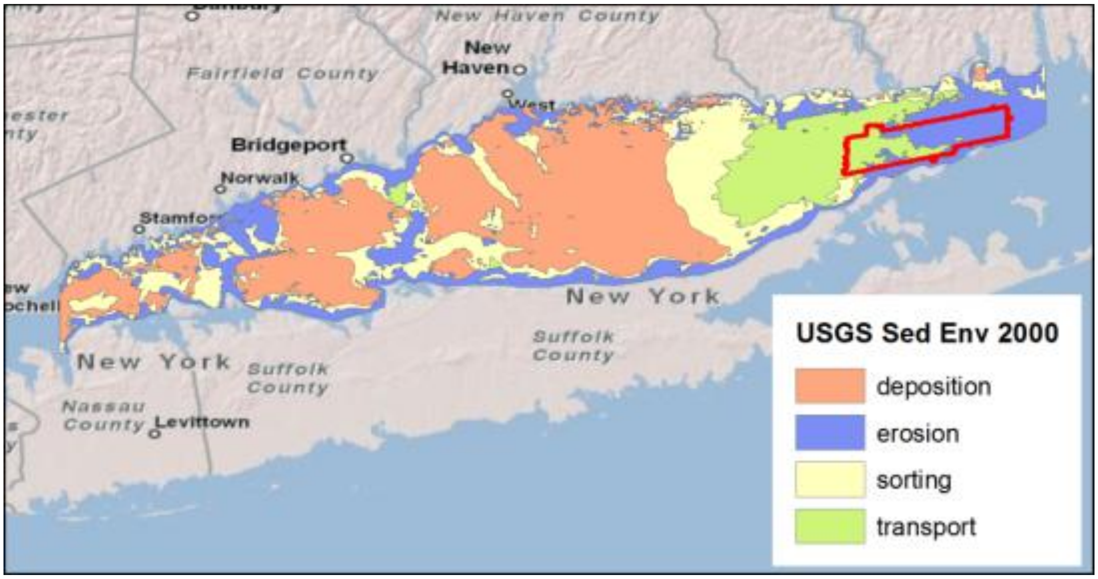

Figure 10.1: LIS sediment environment interpretation (Knebel et al., 1999; Knebel and Poppe, 2000).

This interpretation is incorporates subbottom seismic sparker data that have been collected for the entire LIS at a wide grid with1 - 5 km spacing (Figure 10.2 for pilot study area; (Knebel and Poppe, 2000).

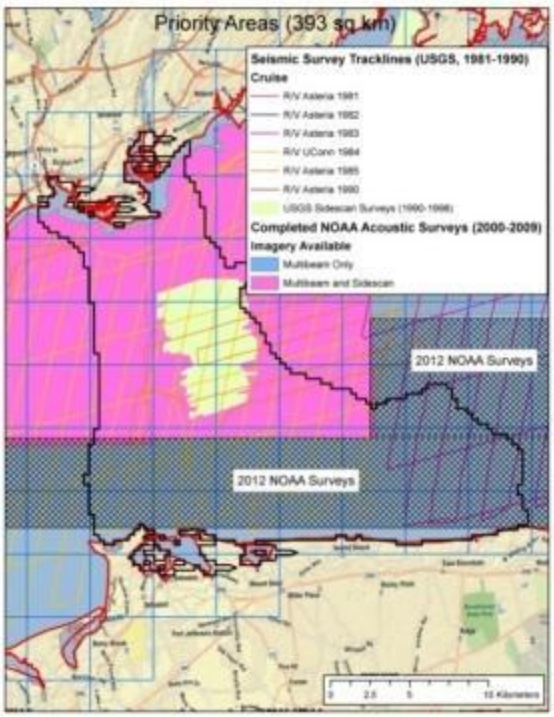

Figure 10.2 - Seismic survey track lines (USGS 1981-1990) for the Pilot Project area in LIS.

10.3. Gap Analysis

10.3.1. Spatial and Temporal Coverage

Although this previous dataset covers almost the entire LIS it is based on data with limited resolution and accuracy. Reinterpretation of a subset using new high-resolution multibeam bathymetry and sidescan sonar data acquired as part of NOAA hydrographic cruise H11997 (Poppe et al., 2011) shows that the details of the interpretation can vary significantly (Figure 10.3).

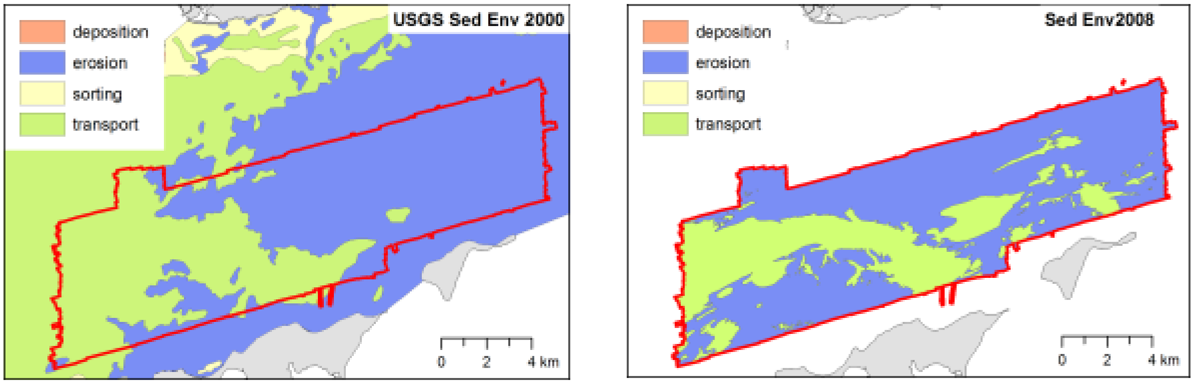

Figure 10.3 - Comparison of sediment environment interpretations in (left) 2000 (Knebel and Poppe, 2000) and (right) 2008 (Poppe et al., 2011). While transport and erosion areas occur roughly in the same area the detail outlines and shape are significantly different. These differences are likely caused by the absence of full-coverage high-resolution bathymetry and backscatter data that were only available for the new interpretation. These data are essential to identify sedimentary environments correctly.

While several patches comparable to Figure10.3. have been reinterpreted after recent high-resolution multibeam surveys, the northern part of the pilot study area, where some newer, detailed data exist (pink in Figure 10.2), has not yet been reinterpreted. The only exception is the area of an older USGS sidescan study (1990-1994, green-yellow patch in Figure 10.2). Especially in the more dynamic section as the central part of the pilot study probably is 10-20 year old data might not reflect the current conditions accurately enough.

To analyze the variability in the interpretation and amount of change between old and new data the sedimentary environments of the entire pilot study area should reinterpreted and compared to the older interpretations.

10.3.2. Suitability

The differences between these data are so significant that they justify an updated interpretation using newly collected data.

In addition to the bathymetry and backscatter data, subbottom information is often essential for correct interpretation of sediment environments, especially to verify deposition and erosion. While existing LIS-wide seismic data outline the general geology such as depth of quaternary sediments the vertical resolution and lateral grid density is not sufficient to identify sedimentary details in the upper few meter and distinguish features in highly variable areas (Figure 10.4). Only a few high-resolution chirp surveys exist in some locations of the LIS that have the desirable resolution.

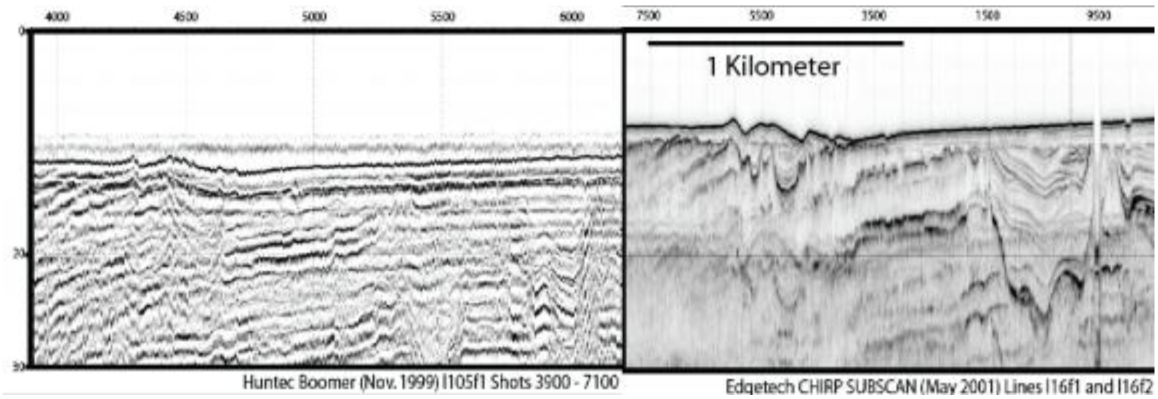

Figure 10.4 - Comparison of older Boomer and modern high-resolution Chirp data (http://woodshole.er.usgs.gov/operations/sfmapping/seismic.htm).

10.4. Required Data

To generate a detailed map/inventory of sedimentary environments requires a joint interpretation that uses multiple datasets. While some sediment environments such as sediment wave and some erosional bedforms can be determined from a combination of seafloor morphology, backscatter, and grain size data, a correct and reliable determination of depositional and erosional requires additional subbottom information from seismic and sediment core data to actually verify these environments.
The different datasets required are:
- bathymetry
- acoustic intensity
- subbottom data
- sediment core description

While a complete subbottom coverage with a grid of 150 m line spacing with 250-500m spacing of cross lines would be desirable to identify and verify larger areas it is likely sufficient to have this high density in areas of significant deposition and/or lateral heterogeneity while maintaining a coarser spacing 500 x 500m in more uniform parts of the study area.
Similarly, sediment cores should focus mainly on suspected, larger depositional areas with some sediment cores taken from other areas as well to verify their non-depositional nature. Thus selection of detailed sediment core locations should be done based on preliminary acoustic products that are available.

10.4.1. Existing Data

Existing high-resolution bathymetry, backscatter, subbottom chirp and sediment core data exist for some locations of the LIS including some portions of the pilot study area. These data should be included into the interpretation.

10.4.2. New Data

In addition to the existing data, new high-resolution bathymetry DEM and backscatter mosaics will be generated that cover the entire study areas (details about these data have been described in previous sections).

Additional high-resolution subbottom data should be collected, especially in areas where deposition and anthropogenic disturbed material is expected. The main emphasize of this study are the upper 1 to 5 meter of sediments. Therefore high resolution is more desirable then deep penetration. Chirp systems, which produce a signal sweep of high quality sound in a defined range of frequencies, can provide the best resolution while maintaining a reasonable penetration. Typical frequency ranges suitable for this study are 4-16 kHz. Navigation should be recorded with at least Differential GPS (DGPS) systems to ensure sub-meter accuracy of the position together with application of a correction for the distance between GPS antenna and towed subbottom unit (layback correction). Correction of vertical position changes due to tidal water level changes should applied. They can be based on Real Time Kinematic GPS (RTK GPS) systems that are capable of resolving vertical changes with a centimeter resolution. Alternatively, a tidal model derived from tide gauges in the area can be used.

The subbottom data should be recorded digitally. Depending on the system used, the data might be originally stored in the system-depending data format. But to maximize their usability raw and final subbottom data should be converted to the industry standard format SEG-Y defined by the Society of Exploration Geophysicist (Barry et al., 1975).

Sediment cores should be collected from key areas to verify depositional nature of the sediments and thickness of top sediment layer. Around 50 new, short (2 m) gravity cores might be sufficient for characterizing the key environments. Collection of sediment cores should be coordinated with other sampling efforts. Basic analysis should include general core description and physical properties to characterize the changes with depth and to verify depositional, erosional conditions, as well as sorting. They can provide important information to link these data with other physical environment measurements. Simple X-ray fluorescence (XRF) measurements, which only take a few hours per core, will verify deposition layers and provide a proxy for estimating deposition rates. While more detailed analysis of the sediment cores are beyond the scope of this project, the cores could be very valuable for future studies and, thus, should be archived for later uses.

Based on the different datasets the following environments should be distinguished and outlined with polygons (Table 10.1):

Table 10.1: Sedimentary environments Classification Scheme for the LIS mapping project.

Class Name	Definition
Erosion/Non Deposition	Ongoing erosional processes evidenced be clearly truncated bedding in the subbottom data, or other information, stratigraphic or radionuclide indicate non-depositional
Bedrock outcrop	Multibeam and backscatter data suggest bedrock outcrops and therefore also non-deposition
Deposition	Characterized by depositional layers in the subbottom data, sediment core analysis, often smooth surface with low backscatter
Sediment waves	Regions with waved imaged with multibeam bathymetry or backscatter data

Sorting	Sediment texture, and acoustic data indicating sorting processes
Transportation	Dynamic areas where sediment texture, and acoustic data indicating sediment transport other then sediment waves, e.g. scour
Pockmarks	Pockmarks are visible in bathymetry and/or backscatter data
Dredged Material	The different datasets indicate that material has been deposited here artificially (e.g. dredge spoil, dump site).
Un-surveyed	Areas that cannot be classified because they have not been included in the survey.

10.5. Delivered Product(s)

The following contains a description of the type of product that will be provided.

10.5.1. Raw Product

See the sections 1 and 2 above for more details about standards for the bathymetry and backscatter products.

The subbottom products include for each subbottom line the digital data in SEG-Y format, a shot-point navigation files that list GPS coordinates and time for the seismic shots, and a jpg or gif image of the subbottom section.

Products for the sediment cores include a table of location, description and acquisition details for all sediment cores as well as results of physical properties and XRF analysis.

10.5.2. Interpreted Product

10.5.2.1. Geospatial imagery and shapefile products

Several interpreted sediment environment GIS products will be delivered at the end of the project. These products are:
(1) a point shapefile of sediment locations with acquisition attributes.

(2) shapefiles of the seismic subbottom lines and shot points.

(2) a shapefile with polygons outlining the different sediment environment classes following the sediment classification scheme above.

Project of these shapefiles will follow the general guidelines for geospatial products outlined in the data management section.

10.5.2.2. Geospatial map products

Digital maps in PDF format will be produced depicting sedimentary environments in the pilot area. Maps showing the locations of seismic lines and sediment samples will also be produced. These maps will be properly attributed with standard cartographic elements and data source references.

10.5.3. Reports and Documentation

In addition to the raw and interpreted data, additional descriptive documentation will be delivered at the conclusion of the pilot project. This documentation will include a report summarizing the key results; describing the methods used, data acquisition, processing, interpretation, and project findings, as well as discussing potential uses of the products listed above. Metadata for all GIS products produced during this project will be delivered along with the report. This metadata will be prepared in an FGDC-compliant format. See the data management section of this report for more details about metadata development and standards.

10.6. Cost and Time Estimates

We assume processed bathymetry and backscatter data are provided as part of other products, so we are not including those.

Subbottom data collection will depend on the spacing of the line that are considerate useful. Coverage of most of the pilot area with 150 m survey line spacing in NS direction and EW cross-lines every 500 m would take about 16 survey days to collect and another 3 month to process. Reducing the subbottom coverage to areas of interest and/or reducing line spacing could reduce the number of survey days to 10.

We assume ~ 40-60 short (1-2m) sediment cores that would be collected on 5-6 days (10 - 15 cores per day), but likely could also be collected as part of the sediment grab sampling and ground verification programs. Basic processing and analyzing of the cores (logging, splitting, archiving and processing would take about 4 months. Data interpretation and creation of products would take 3-4 months.

10.7. References

Barry, K.M., Cavers, D.A., Kneale, C.W., 1975. Recommended standards for digital tape formats. Geophyics 40, 344-352.

Knebel, H., Poppe, L., 2000. Sea-floor environments within Long Island Sound: A regional overview. Journal of Coastal Research 16, 533-550.

Knebel, H.J., Signell, R.P., Rendigs, R.R., Poppe, L.J., List, J.H., 1999. Seafloor environments in the Long Island Sound estuarine system. Mar. Geol. 155, 277-318.

Poppe, L.J., McMullen, K.Y., Ackerman, S.D., Blackwood, D.S., Schaer, J.D., Forrest, M.R., Ostapenko, A.J., Doran, E.F., 2011. Sea-floor geology and topography offshore in Eastern Long Island Sound:. U.S. Geological Survey Open-File Report 2010–1150 http://pubs.usgs.gov/of/2010/1150.

11. PHYSICAL AND CHEMICAL ENVIRONMENTS

11.1. Importance and Need

Priority products identified in the 2011 mapping workshop included water properties (salinity, temperature, dissolved oxygen (DO) concentrations and bottom stress patterns. These variables are central to characterizing the environment and for the determination of the extent of impact of impact of management decisions on, for example, fisheries and construction projects.

Fisheries

Understanding and predicting impacts of management actions on ecosystems requires an appreciation of the environment. Characterization of the benthic habitat is particularly important. Critical species functions like feeding and reproduction are often sensitive to temperature and dissolved oxygen (DO) concentrations. For example, characteristics of the fish populations in the Sound have been shown to be sensitive to water temperatures and the reproductive success of lobsters are thought to be sensitive to the area of the bottom that is cooler than 20.5 C. Management of competing uses must be informed by the boundaries of these critical habitats. Salinity, Ph, nutrient concentrations, turbidity, and light levels are also likely to important other species. Some of these parameters, and their correlation scales, have structure that varies with season. Bottom temperature and DO, for example, have annual cycles that are well established in the deeper areas of the Sound. Mapping products must describe this variability throughout the Sound.

Infrastructure and Dredging

Bed stability and the processes that control geochemical exchange are also important components of permitting decisions so parameters like wave and current induced bed stress, bottom roughness, and critical erosion shear stress are necessary complements to the sediment size and density maps. The selection of sites for the disposal of dredged sediment, the path of cables and pipelines, and large bottom mounted or moored energy infrastructure projects will require knowledge of currents, waves, bottom sediment erosion/deposition potential.

The bottom stress and sediment characteristics determine erosion and deposition rates. The circulation and wave field largely determines the stress. The circulation also controls the path of particles in the Sound. So the fate of materials introduced to the Sound by discharges and construction activities is largely controlled by water movement. The extent of the influence of water withdrawal for cooling /gasification etc., and the connectivity of populations is also controlled by circulation. A Sound-wide database of the these parameters and their statistics will inform planning and facilitate decision making by project developers and regulators..

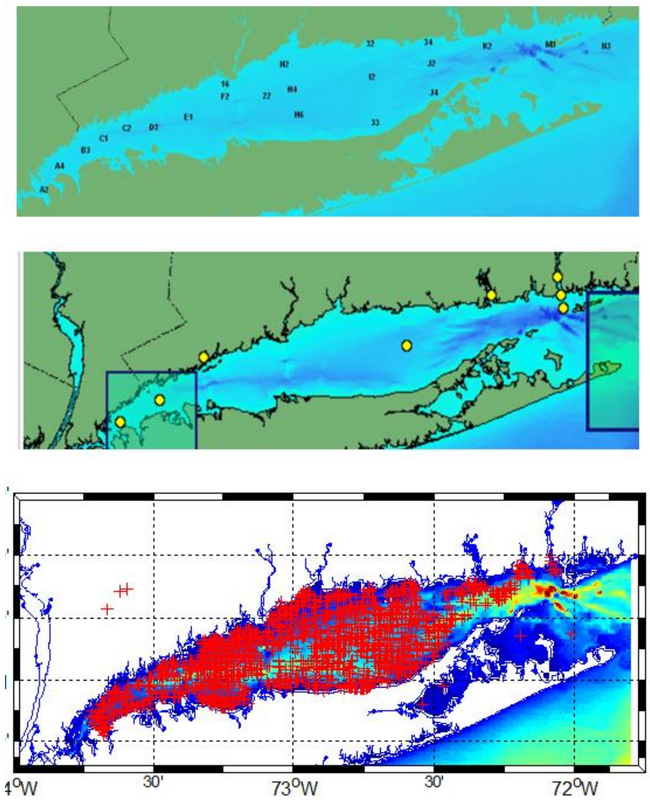

Figure 11.1: (a) Location maps for the primary (year round) station occupied by the CT DEEP cruise; (b) the location of LISICOS buoys; and (c) locations of available salinity- temperature profiles from the CT DEEP fisheries surveys.

11.2. Background and Existing Data

There is an extensive archive of salinity and temperature, nutrients and DO at ~20 sites in the Sound from ship surveys and at three buoys (see Figure 11.1a, b, and c). Data is available at the http://lisicos.uconn.edu/. Since 1987 the CT DEEP has also conducted ship surveys in the summer to inventory fish species and they also collect salinity and temperature profiles. Some station locations are visited each year and others are randomly selected. The distribution of stations is shown in Figure 1c. A coastal sea surface temperature product is derived from satellites and distributed by the University of Delaware at http://orb.ceoe.udel.edu/maps/MARCOOS_SST. However, there has been no comparison of this product and *in situ* observations.

A preliminary example of an analysis product that can be developed using ship and buoy data is shown in Figure 11.2. It is an estimate of the bottom temperature distribution in July 2007. The extent of the eastern Sound warmer than 21C is an important determining factor in the success of the Lobster population. This analysis product is statistically consistent with the ship surveys and covariance functions estimated from moored temperature recorders. It is displayed in

GoogleEarth with a time-slider that allows the user to visualize the evolution of spatial variations with season. Similar products can be developed for other habitat characteristics, e.g., DO and salinity, and made available in a variety of formats for inclusion in GIS viewer.

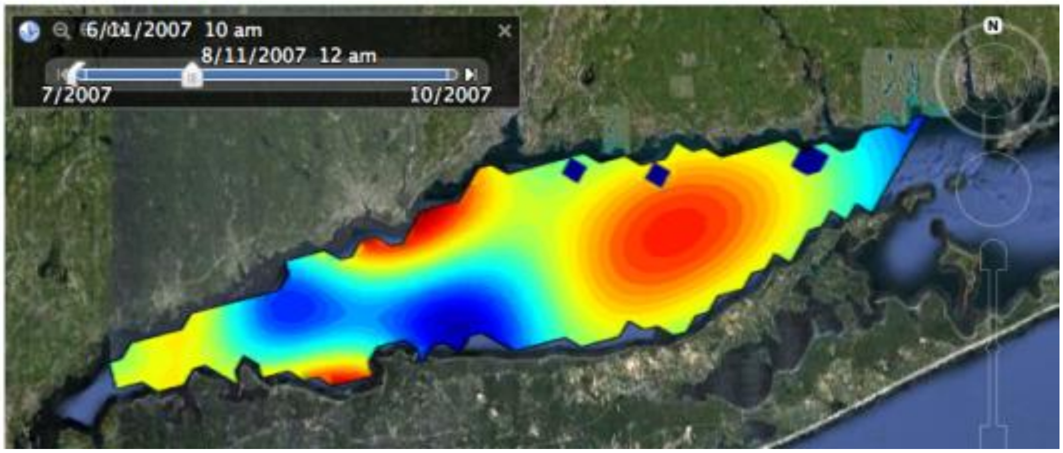

Figure 11.2: Bottom temperature analysis for July 2007.

There are also an extensive current meter archive thought it is not readily accessible. Figure 11.3 shows the locations of current profiling instrument records. There are wave observations available at the LISICOS buoys and data can be obtained from http://lisicos.uconn.edu/ or http://www.ndbc.noaa.gov/.Though several circulation models have been developed to simulate water motion, only Signell and List (1997) have published maps of the maximum current, wave amplitude and period, bottom stress etc. However, little current meter data and no wave observations were available during their study period and the products are not available in a digital format. More sophisticated models are now available and the existing data should be assimilated to create products showing the distribution and variability of currents and bottom stress in formats that can be widely shared.

Maps of bottom sediment type and size in Long Island Sound have been created by USGS (http://pubs.usgs.gov/of/1998/of98-502/chapt1/chpt1.htm#distribution) for waters greater than 10m deep. They have also categorized regions of deposition, erosion and transport. However, the parameters that characterize their stability of the sediment and the rates of erosion and transport have not been reported.

Figure 11.3: Location of existing current meter records.

11.3. Gap Analysis

There are no geospatial products that provide maps of the parameters that describe the physical-chemical environment near the bottom of Long Island Sound.

Data that is adequate to characterize the Sound-wide patterns in temperature, salinity, dissolved oxygen, nutrient concentrations, circulation and stress are largely available. However, there are few archived measurements between the intertidal zone and the 10m isobath. Turbidity and light level at the bed, bed stress, and roughness have only been measured at a few spots.

A major weakness in the available data is that instruments don't get all the way to the bottom at most sites and the temporal variability information is sparse. This is critical to interpolation of observations and to the characterization of habitat. There are a few temperature records from lobster trap temperature sensors that are very helpful in the eastern Sound.

11.4. Required Data

A climatology of salinity, temperature, DO, can be assembled using existing data but since it is sparse near the edges of the Sound the uncertainty will be large there. Since the spatial autocorrelation scales are likely to be shorter in the summer, the emphasis for data gathering should be areas as far as possible from the stations shown in Figure 11.1a.

The program should ensure that CTD, DO, turbidity, light level, measurements be conducted at all stations occupied and ADCP measurements be acquired on all transects during the mapping activity. Vessels with ship mounted ADCP and surface CT instruments should be used.

Bottom sensors for salinity, temperature and DO sensors should be deployed at the 3m isobath in the vicinity of operations to establish the time variability and correlation scales for analysis.

Bed stress using bottom tripods and ADCPs at examples of all habitat units to measure bed stress, turbidity and resuspension rates.

11.5. Delivered Product(s)

11.5.1. Raw Product

The measurements will be included in an archive referenced by time, position, depth of sample below surface and local bottom depth. The time series and the time-space series from ADCPs will be archived as well. In addition, these new observations will be augmented with the existing observations. Comprehensive metadata that conform to existing and emerging standards will be collated and linked to the data archive.

11.5.2. Interpreted Geospatial Products

The project will produce both raster (gridded) fields and shape files with contour locations for bottom distributions of salinity, temperature, turbidity, dissolved oxygen, current speed and direction, and current, wave, and combined wave-current bottom stress. The analysis to develop the temperature, salinity, turbidity and DO maps will four dimension objective analysis with covariance functions that are estimated from survey and mooring data. Since current, wave conditions and stress measurements are likely to be sparse and of limited duration, map products will be developed using a model with data assimilation. The resulting maps of bottom current, wave velocity and the consequent bottom stress will then be consistent with the observations of current by ships and the moored profiler observation (see Figure 11.3), wave observations at the CLIS and WLIS buoys. The model employed has already been developed with the support of the CT Sea Grant Program, the NOAA IOOS program through NERACOOS, and the EPA Long Island Sound Program so products will be available shortly after the observations become available.

11.6. Cost and Time Estimates

Since much of product development discussed here depends upon existing data and new measurements acquired during operations for other purposes, much of the costs are associated with personnel for data processing and product development. For the pilot year a Postdoctoral Research assistant and graduate student will be necessary and the costs should be approximately $120,000. For the sediment stability and transport products measurements will be required and the technical support associated with these activities will be approximately $60,000.

11.7. References

Signell, R.P., and List, J.H., 1997, Effect of wave-enhanced bottom friction on storm-driven circulation in Massachusetts Bay, ASCE Journal of Waterway, Port, Coastal and Ocean Engineering, v. 123, n. 5, pp. 233-239.

12. PROJECT TIMELINE, OPERATIONAL SUMMARY, AND GENERALIZED COST ESTIMATE

In an effort to provide the Steering Committee perspective on timing and operational design of the Pilot Project, the Habitat Sub-Group has prepared several models to describe the work-flow process. Additionally, the collaborative teams has prepared a "Rough Order of Magnitude" (ROM) Cost Estimate to provide preliminary details on the relative costs of each of the components entailed in completing the Phase I – Pilot Project for Long Island Sound. Every effort has been made to optimize the sequencing and project work flow despite the difficulties of a collaborative teaming construct. However, it is recognized that additional efforts will be needed to provide more detailed scheduling and operational planning before the commencement of work. This more rigorous planning activity will be initiated upon final acceptance of the Scope of Work by the Steering Committee but before the collection of data actually commences.

Furthermore, it must be understood that a ROM cost estimate is a first-order planning tool. The costs presented have unknown margin of errors associated with them.

12.1. Timeline

The Pilot Project is anticipated to require approximately 15 months to complete, upon initiation of the contract awards May 1, 2012 (Figure 12.1). NOAA data collection is anticipated to begin May 1, 2012, therefore planning activities will occur during the period of time preceding the acquisition start (March – April 2012). These planning activities include: 1) finalizing the classification scheme to be used across all the components, 2) developing a detailed work plan and Gantt Chart, 3) finalizing the database management construct and standards, 4) aggregate and assess the utility of existing data, 5) developing accepted guidelines for new data acquisition, and 6) develop sampling plans for data collection (See Figure 12.2: T1 – Synthesis and T2 – Sampling Plan).

From May to July 2012, acoustic collections will occur both by NOAA and academic partners. These collections will occur in regions where data gaps exist in current coverage and they include deep water portions of the Sound (20-50m), mid water depths (>4-20m), and very shallow water portions (<4m). It is proposed that acquisition will also revisit areas previously mapped by NOAA to increase data densities (Figure 12.2: T3 – Field Effort, Acoustic (A)). To the extent possible, sub-bottom data acquisition will occur simultaneously on these vessel platforms (Figure 12.2: T3 – Field Effort, Sediment Environment (B)). Preliminary processing of these acoustic data will also occur to support Sediment, Physical, and Ecology field data collection (Figure 12.2: T4 – Preliminary Results, Acoustic (A); T3 – Field Effort, Sediment Environment (B), Sediment Texture (C), Ecology and Habitats (D), and Physical Environment (E). Processing of all of these datasets will be initiated (Figure 12.2: T5 – Processing).

From November 2012 to March 2013, newly collected field data will be integrated with existing data to provide a synthesis data set. (Figure 12.2: T6 – Integration). Final datasets (Figure 12.2: T7 – Final Data) and Final products (Figure 12.2: T8 – Final Products) will be produced for each of the components.

From April 2013 to July 2013, the teams will initiate an analysis of the overall assessment of project components. A second series of ecological field data will be collected to explore the seasonality associated with the ecological characterization and habitat mapping, with results integrated into the final products as needed (Figure 12.1). The final report will be delivered to the Steering Committee followed by an oral presentation to the Steering Committee on the assessment of the Pilot Project. At the conclusion of this assessment, the team will begin planning efforts for Sound-wide work.

12.2. Operational Plan

The operational plan for the Pilot Project is presented in Figure 12.2. This diagram provides an initial perspective about the sequence and dependencies of work plan activities, but a more detailed operational plan will need to be developed prior to the commencement of work efforts. A subsequent operational plan will be in the format of a Gantt chart which clearly articulates what activities each team will perform, when, detailed timelines, and task dependencies.

The operational chart included does indicate a number of critical work plan dependencies (red arrows). A number of component tasks require shared informational content in order to inform the design of efficient and accurate sampling strategies. The inter-dependency of the various components is particularly evident in the development of Final Products. The information derived for each of the respective components provides valuable explanatory application towards the development of other dependent Final Products.

12.3. Cost Estimate

The Habitat Sub-Group was asked to develop a preliminary, Rough Order of Magnitude (ROM) cost estimate for the components proposed in the Scope of Work (Figure 12.3). However these ROM costs should be considered in the context of several factors that have precluded more successful outcomes:

1. It has not been explicitly determined which of the Consortium teams, or mixture of teams, will be conducting each of the components. As the inter-Consortium team discussions and agreements have not been formalized, it is likely there will be cost-saving opportunities if the partition of effort was more explicit.
2. It has not yet been explicitly determined if all of the components and all the elements of a respective component will be fully funded.
3. Vessel cost and field data collection piggy-backing opportunities have not been fully explored due to the vagaries of the items listed above.
4. The ROM cost estimate is believed to have a high margin of error, as will subsequent cost efforts, until it is formally decided what will be conducted, at what level of effort, where, and by whom.

The ROM has intended to capture the Labor, Materials & Supplies, Travel, Vessel Costs, and Indirect Rates for each of the components. For ease of review, acoustic data collection has been sub-divided into deep-water and shallow-water. Notes have been included to capture cost ambiguities or potential cost-savings were identified. Component costs were separated by

Consortium team where they were provided. The exception to this was the Database Management component, wherein the costs were combined.

As proposed in Sections 1 through 12 in Scope of Work, the Pilot Project was estimated to cost approximately $1,543k comprised of $816k of Labor, $166k of Materials and Supplies, $28k of Travel, $450k of Vessel cost, and $83k of Indirect cost (Figure 12.3). The Consortiums were directed to maintain Indirect costs below 10%. NOAA has no Indirect costs. Additionally, the NOAA in-kind vessel and federal labor was not indicated although it is estimated to be approximately ~$1,500k for the Pilot Project.

While this ROM estimate does not satisfy the directive given by the Steering Committee that the Pilot Project not exceed $1 million cost, it does provide useful cost metrics to guide further cost reduction strategies. There are a number of possible options that may be explored that may help satisfy and meet that threshold, however the ramifications of those options must be thoroughly considered and captured before implementation. The following are possible cost-reducing options, but there may be others not presented here which are worth considering.

1. ***Explore further vessel sharing*** – The cost ROM estimates were calculated independently by each of the Consortiums, but with little consideration given as to how vessel time could be optimally managed to reduce cost. Figure 12.3 alludes to a number of these opportunities: sub-bottom collection during acoustic surveys, sediment grabs and cores during ecological or physical environment sampling. However, the practicality of implementing a piggy-back field collection approach is uncertain. In some instances it may not by feasible or cost-effective to conduct such activities, but nonetheless the opportunity for additional vessel costs sharing must be more thoroughly explored before proceeding further.

2. ***Reduce the size of the pilot project*** – While it is not expected there is a linear relationship between cost and Pilot Project area, it is anticipated that a reduction in the project size would contribute to a proportionate reduction in labor and vessel costs. There are a number of ways in which the Pilot Project area could be reduced, but exploring these is dependent on thoroughly understanding the spatial priorities by depth and distance from shore. For example, if the very shallow water environments (<4m) is determined to be of lower priority, these areas could be eliminated. If they are determined to be of equal priority, than representative sub-regions within the Pilot Project area could be chosen with the anticipated effect of cost reduction.

3. ***Reduce component tasks*** – The Scope of Work provides recommendations on what activities should be conducted for the Pilot Project, but further prioritization of essential tasks should be thoroughly explored. Are there elements of the components that are not essential and can be eliminated? Are there elements that could be deferred to a later time period once results from the preliminary work are completed? Could field data for some elements be collected, but deferring analysis to a later time?

4. ***Negotiate component costs*** – The Consortiums have presented cost estimates for components, but consideration should be given as to whether a satisfactory "reduced" product could be achieved at a lower cost. For instance, could the sampling effort, product spatial resolution, or the product thematic detail be reduced to provide a more cost-effective, yet acceptable product?

One hypothetical scenario for implementing the cost-costing measures stated above is as follows:

a) Reduce labor costs such that $120k is allocated towards field data collection and $360k towards the post-processing and product development. This represents a conservative 3:1 ratio of post-processing for every hour of data collected.
b) Maintain Materials and Supplies at $165k as these are typically fixed costs.
c) Maintain Travel at $30k as these are typically fixed costs.
d) Implement vessel sharing for data collection such that the total cost across all components does not exceed $275k.
e) Given the above, the Indirect total (%10) applied to Labor would be $48k.
f) Revised Pilot Project total under this scenario is $997k

	ROM Estimate	Hypothetical Scenario
Labor	$816,299	$480,000
Materials and Supplies	$166,000	$166,000
Travel	$28,000	$28,000
Vessel	$450,000	$275,000
Indirect Rate	$83,000	$48,000
Total	$1,500,000	$997,000

Further direct and explicit guidance from the Steering Committee can help to clarify any ambiguities or perceptions of a components relative importance by the Consortiums. While the Consortiums have compiled a worthy list of recommendations and options in the Scope of Work, ultimately the Steering Committee must provide unequivocal direction as to which components and elements should proceed further. In order to ensure subsequent technical and proposal development is productive, the Steering Committee should provide its recommendations to the Consortiums. They Consortiums should then convene a meeting to consider how those recommendations should be implemented, clarify their respective roles and levels of effort, and develop their respective cost and technical proposal bids.

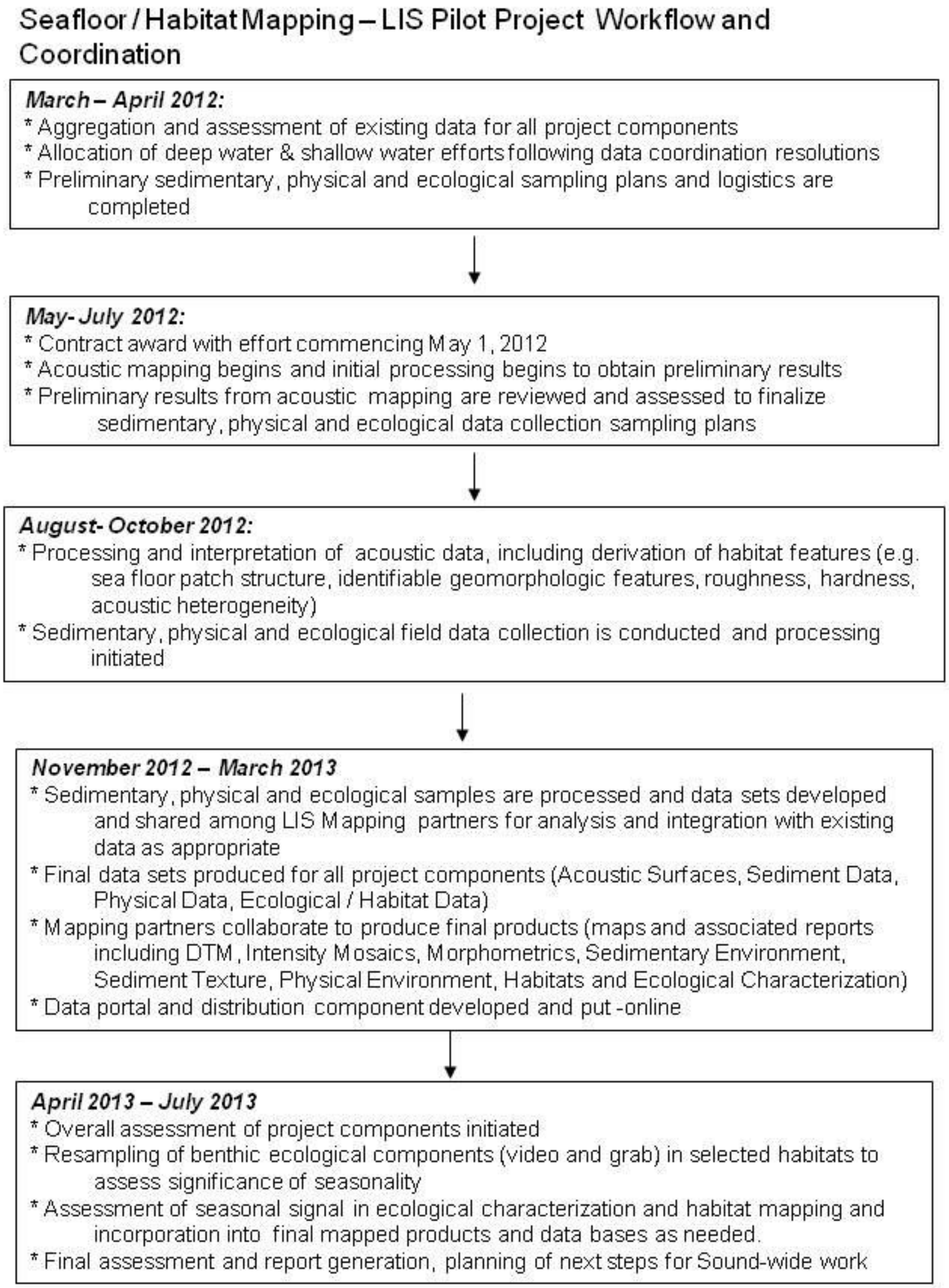

Figure 12.1: Scheduling Plan for the Pilot Project

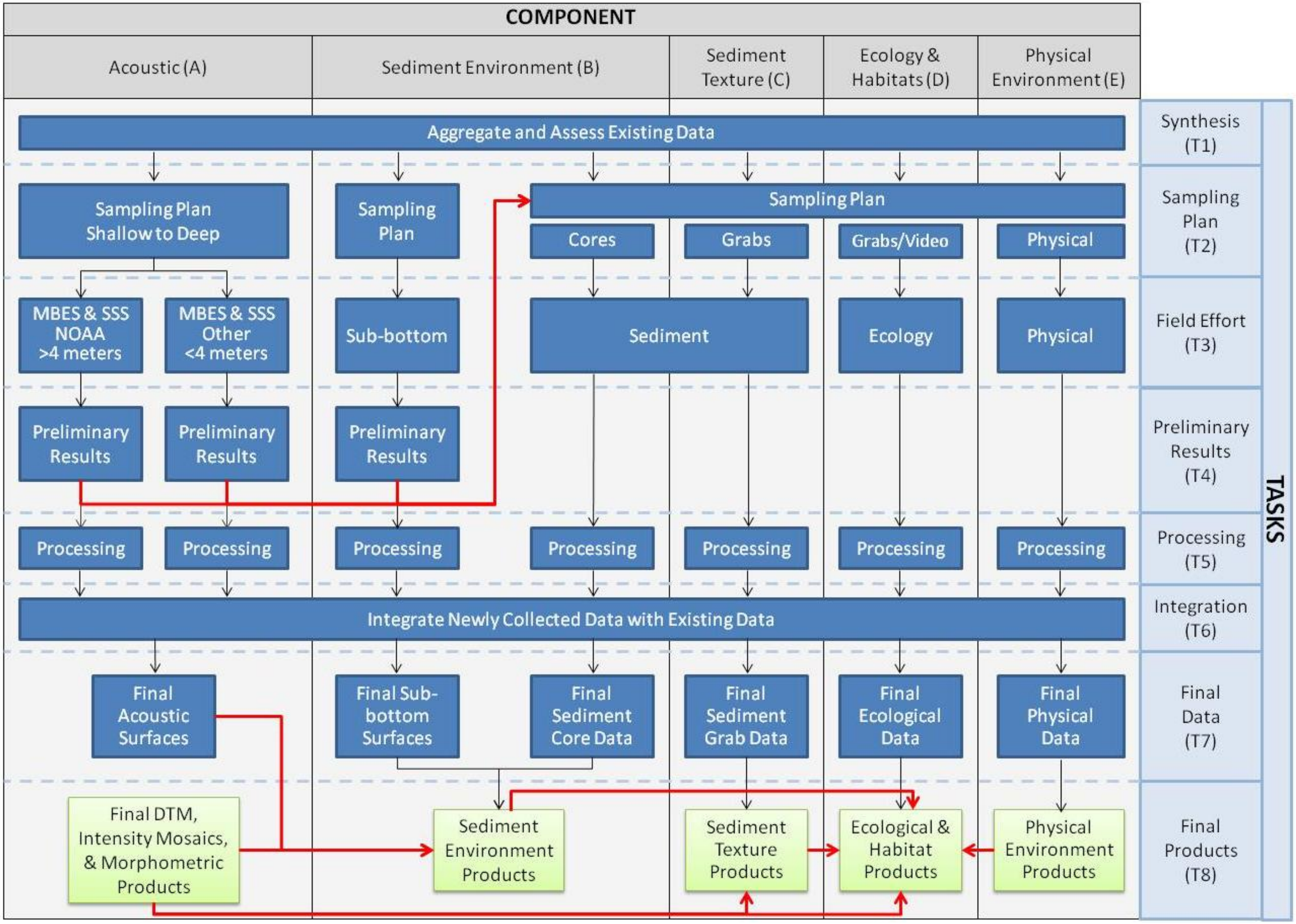

Figure 12.2: Pilot Project Operational Chart per Task and Component