National Wetlands Research Center
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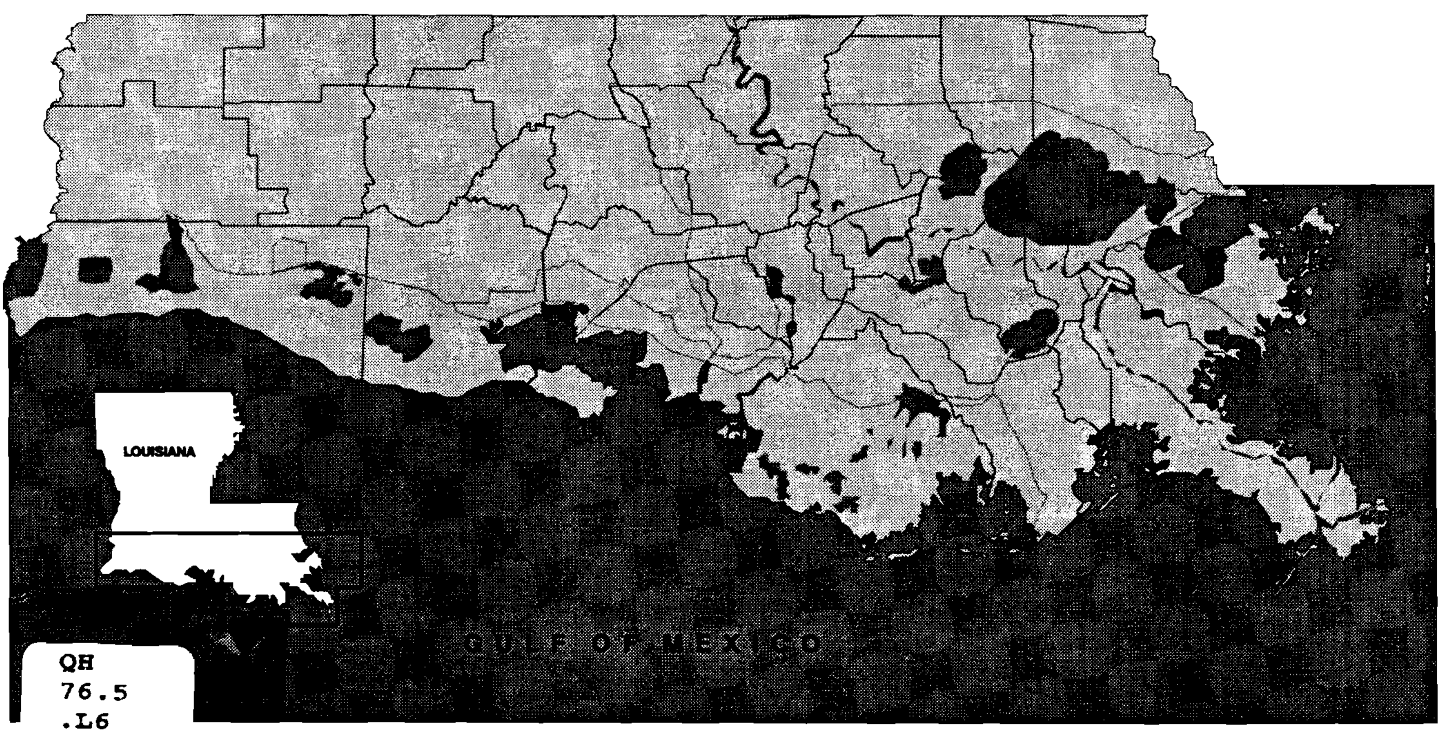
MONITORING PROGRAM FOR COASTAL WETLANDS PLANNING, PROTECTION, AND RESTORATION ACT PROJECTS



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Monitoring Program for Coastal Wetlands Planning, Protection, and Restoration Act Projects

Submitted by

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Contents

EXECUTIVE SUMMARY

Louisiana's coastal wetland loss, estimated at 79.5 km^2/year, has drawn national attention. In response, the Coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA) was created to provide the guidance and means to develop and implement a project-oriented program to combat this coastal wetland loss. The CWPPRA requires a monitoring program be established to evaluate the effectiveness of these projects.

Projects developed under this program range from massive freshwater and sediment introduction to small scale vegetative plantings. Currently, there is no available standardized method for monitoring variables that can determine success or failure of wetland restoration projects. Consequently, data collected by Federal, State, and local entities within the coastal zone of Louisiana have not been comparable, and thus of limited use. The committee charged with the development of this monitoring program felt it was imperative to develop standardized protocols that could be used to judge project success or failure. Over 100 Federal and State restoration projects are currently being planned, and with standardized protocols, usable and comparable information will be generated, aiding in resource management and future planning and design.

These monitoring protocols were developed in response to the mandate for procedures that would evaluate the effectiveness of each coastal wetlands restoration project in achieving long-term solutions to arresting coastal wetlands loss in Louisiana. Specifically, this mandate requires that a scientific evaluation be conducted to test the effectiveness of these projects in creating, restoring, protecting, and enhancing coastal wetlands in Louisiana.

These monitoring protocols broadly categorize project types, goals, and biological variables, and standardize data collection methodologies using a matrix design. This organization provides accessibility to three levels of information: project type, category of variable, and variable. These three levels are cross-referenced and ranked to guide personnel in the development of appropriate monitoring plans.

The goal of the monitoring protocols is to provide a guidance document that can be used to develop project-specific and basin-wide monitoring plans and monitoring cost estimates. In addition, the protocol should help determine the minimum monitoring standards necessary to provide sufficient information to determine whether project-specific goals are met.

Monitoring protocols were developed by subgroups of technical experts for seven categories of monitoring variables: water quality, hydrology, soils and sediments, vegetative health, habitat mapping, wildlife, and fisheries. Some variables were identified as a monitoring priority by more than one subgroup, but only one subgroup will describe specific methodologies and costs (Table 1). The results of each subgroup are represented in the following sections of this document. Each section described protocol design, cost estimates, priority rankings, and existing data bases. Following is a general overview of the monitoring protocols each monitoring subgroup developed.

Water Quality

The water quality monitoring subgroup identified physical variables, salinity, temperature, nutrients, and priority pollutants as essential in designing a water quality monitoring plan for CWPPRA projects. Sampling methodologies vary widely in degree of sophistication as well as frequency (instantaneous, continuous recorder, realtime). The water quality monitoring subgroup feels that specification of sampling frequency is premature at this time and that sampling frequency will vary according to the availability of preexisting data, size of the project area, type of restoration project, and cost. Costs were estimated on a per sample basis and are illustrated by project type in Table 2.

Hydrology

The hydrologic monitoring subgroup identified variables to be monitored that would assist in determining project success as well as design of future projects. The variables are precipitation, evaporation, wind speed and direction, water level, bathymetry, topography, salinity, discharge, suspended sediment, ground water, and soil salinity. A majority of these variables can be monitored on a single data collection platform to provide realtime data, reduce maintenance costs, and minimize data loss. Cost estimates will vary according to frequency of data collection and number of sampling stations (Table 2).

Soil and Sediments

The soil and sediments monitoring subgroup identified variables that can be measured in the field to evaluate the success of CWPPRA projects in promoting soil development. The variables are organic matter content, bulk density, water content, grain size, soil redox, soil nutrients, soil contaminants, vertical accretion, subsidence, and soil erosion or creation. Vertical accretion and subsidence measurements can use three different methodologies depending on monitoring intensity: feldspar markers, sediment erosion table or radionuclide dating for accretion and carbon-14 dating, global positioning systems (GPS), and extensometers for subsidence. Estimates of total will vary tremendously depending on monitoring intensity and frequency as illustrated in Table 2.

Vegetative Health

The vegetative health monitoring subgroup determined that the following four variables were essential in evaluating vegetative health responses to CWPPRA projects: species composition, relative abundance, aboveground biomass, and herbivory. It was recommended that the Braun-Blanquet method be used for quantifying shifts in community compositions and abundances; that the clip-plot method be used for quantifying aboveground biomass; and that exclusion techniques be used to estimate the impacts of herbivory. Project-specific goals and available resources will dictate what and how frequently vegetative health variables will be monitored. Cost estimates by project type are illustrated in Table 2.

Habitat Mapping

The habitat mapping subgroup developed a two-phased monitoring approach. At the first level, basin-wide mapping at a scale of 1:100,000 is proposed. Data at this level could provide a quick

land and water classification to assess wetland trends for large restoration projects and entire hydrologic basins. The second level mapping is at scales ranging from 1:6,000 to 1:12,000. The Cowardin et al. classification is used for those restoration projects that require a greater level of detail. Habitat mapping will be conducted on all projects and will be prioritized based on project implementation timetables. Cost estimates by project type are illustrated in Table 2.

Wildlife

The wildlife monitoring subgroup recognized that wildlife populations are secondary to full recovery and conservation of coastal wetlands. The subgroup further recognized that wildlife populations are influenced by a broad range of factors, many of which are external and unrelated to basin-wide habitat conditions. For these reasons, the subgroup felt strongly that project evaluation should be based on monitoring variables that are expected to respond directly to restoration projects, namely water quality, hydrological, and vegetative variables. The subgroup agreed that, over the long term, recovery of coastal wetlands would benefit wildlife populations in the region. Wildlife populations or the effects of herbivores on vegetation will have to be monitored in case of herbivore demonstration projects.

Fisheries

The fishery monitoring subgroup determined that monitoring should target juvenile fish and crustaceans with emphasis placed on the collection of quantitative samples using high catch-efficiency gear. In addition to measuring animal density as an indicator of project area or habitat value, information on animal size, biomass, and species richness should also be collected. For oysters, measurements of growth, survival, and spat settlement should be collected. The gear type selected for sampling is throw traps. Sampling intensity and frequency depend on size of project area, number of different habitats present, and cost. Cost estimates by project type are illustrated in Table 2.

The standardized monitoring protocols developed in this document will provide statistically defensible, scientific procedures for monitoring those variables critical for determining project success or failure. It provides the framework and flexibility to develop basin-wide and project-specific monitoring plans while at the same time identifies the degree of effort and resources needed to accomplish this monitoring.

I. INTRODUCTION

Wetland loss in Louisiana has been caused in part by subsidence and natural delta senescence (Boesch et al. 1983), channelization of the Mississippi River (Frazier 1967), saltwater intrusion (van Beek and Meyer-Arendt 1982), and canal dredging along with other mineral exploration and extraction activities (U.S. Environmental Protection Agency 1987; Craig et al. 1979). Reductions in freshwater and sediment inputs caused by changes in wetland hydrologies have been key to this substantial loss.

Louisiana is experiencing the most critical coastal wetland erosion and land loss problem in the United States, accounting for nearly 80% of the nation's coastal marsh loss (U.S. Army Corps of Engineers 1987a). Shoreline erosion rates exceed 6 m/year in more than 80% of the Louisiana coastal zone and can reach up to 50 m/year in areas impacted by hurricanes (Suter et al. 1989). Continually impacted by a combination of natural forces and human activity, Louisiana coastal marshes lose an estimated 79.5 km^2/year (Dunbar et al. 1990).

The need for comprehensive, large-scale restoration action has been documented by state and federal agencies in several reports (U.S. Army Corps of Engineers 1987b; U.S. Environmental Protection Agency 1987; State of Louisiana 1988—Appendix A). In Louisiana, efforts of State and Federal agencies are currently underway to develop a comprehensive wetland conservation and restoration plan. This and other restoration efforts require that informed decisions be made in order to implement successful projects. In their action agenda, the National Wetlands Policy Forum (1988) specifically stated that "the ability to evaluate restoration efforts is severely limited because readily usable, accurate techniques for measuring or monitoring functions do not exist."

In response to accelerated wetland loss in Louisiana, Act 6 of the 2nd Extraordinary Session of the Louisiana State Legislature in 1989 and the Coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA) of 1990 were created to conserve, restore, create, and enhance Louisiana coastal wetlands. The agencies responsible for designing and implementing coastal conservation and restoration projects include the Louisiana Department of Natural Resources, U.S. Department of Commerce, U.S. Department of Agriculture, U.S. Department of the Interior, U.S. Department of the Army, and the U.S. Environmental Protection Agency. The restoration plans developed pursuant to these acts specifically require an evaluation of the effectiveness of each coastal wetlands restoration project in achieving long-term solutions to arresting coastal wetlands loss in Louisiana. They necessitated the development of a monitoring program to adequately assess the success or failure of coastal restoration projects. The above agencies have a responsibility to the State of Louisiana, and to the nation, to develop a monitoring program that will effectively ensure the best use of State and Federal funds for the restoration and conservation of wetlands.

The CWPPRA created an interagency task force and charged it with the development and implementation of a comprehensive approach to the long-term conservation and restoration of coastal wetlands. Because in a broader context, the mission of the CWPPRA is to provide appropriate management plans for the Louisiana coastal zone over the next 50-100 years, monitoring protocols could be applied on a regional scale across the coastal zone to provide the data necessary for effective management planning at that scale. The CWPPRA requires that not less than 3 years after the completion and submission of the restoration plan, and at least every 3 years thereafter, a report shall be made to Congress containing a scientific evaluation of the effectiveness of the coastal wetlands restoration projects in creating, restoring, protecting, and enhancing coastal wetlands in Louisiana. Consequently, the purpose of this monitoring protocol is to evaluate the effectiveness of the projects selected for inclusion in the plan in achieving their stated goals. To address these monitoring requirements, a monitoring work group was established under the Planning and Evaluation Subcommittee of the CWPPRA Technical Committee (Figure 1). This report represents the efforts of the monitoring work group.

II. OBJECTIVE

The monitoring work group consisted of representatives from Federal and State agencies, as well as academia. The specific responsibilities of the monitoring work group were 1) to develop a monitoring program to evaluate the effectiveness of each coastal wetland restoration project in achieving long-term solutions to arresting coastal wetland loss in Louisiana, 2) to document the effectiveness in reports to the U.S. Congress and Louisiana legislature, and 3) to make recommendations to the CWPPRA Task Force for the allocation of monitoring funds properly.

To accomplish these responsibilities, the following goals were established: 1) to develop standardized protocols for monitoring variables, 2) to develop statistical review procedures, and 3) to develop quality assurance and quality control procedures. All three goals will lead to detecting change between the pre-project condition and the post-project condition in Louisiana wetlands. This will help determine if the project is working and whether midcourse corrections are necessary.

In pursuit of these goals, group members envisioned a monitoring program that would consider

1) Nine types of restoration projects;
2) Project-specific goals (hypotheses);
3) Wetland values as determined by a wetland value assessment (WVA) procedure;
4) Site-specific as well as basin-level effects of projects; and
5) Existing monitoring activities occurring in coastal Louisiana.

Similar monitoring needs exist within and between each type of restoration project, and the development of standard protocols for these similarities are the backbone of the monitoring program. Monitoring methods and protocols for restoration projects were developed by technical experts for seven categories as follows:

1) Water quality
2) Hydrology
3) Soil and sediments
4) Vegetative health
5) Habitat mapping
6) Wildlife
7) Fisheries

The protocol design was developed to broadly categorize project types, goals, ecological variables, and data collection methodologies.

III. DESIGN

Restoration Project Types

Under Act 6 and the CWPPRA, all projects were categorized into nine types: freshwater introduction and diversions, sediment diversions, marsh management, hydrologic restoration, beneficial use of dredged material, shoreline protection, barrier island restoration, vegetative planting, and sediment and nutrient trapping.

Freshwater introduction and diversion

Freshwater introduction and diversion projects are designed to introduce fresh water and alluvial material from available sources to shallow marsh estuaries. Areas targeted for freshwater diversion projects are characterized by saltwater intrusion, sediment subsidence, and shoreline erosion. The primary goal of these projects is to enhance wetlands by increasing the use of fresh water, nutrients, and sediments that will be provided by the freshwater diversions. Management of the outfall will route the fresh water through the wetlands and provide greater deposition of sediments in the marsh to offset subsidence, greater availability of nutrients to vegetation, and a more gradual release of fresh water to the benefit of wildlife, fish, and shellfish. Monitoring freshwater diversions will help to determine if any changes or modifications are needed in the operation.

Sediment diversion

Sediment diversions are projects that increase deposition of river-borne sediment in shallow bay areas that cannot keep pace with subsidence through sediment accretion. A small-scale sediment diversion project is designed around the concept of natural crevasse splay development, where a breach occurs in the bank of a river, sediment infilling begins within the surrounding distributary bays, and crevasse splay sediments eventually become subaerial and established with marsh vegetation. Large-scale sediment diversions on the Mississippi River are designed to be similar to the large natural crevasses such as the one at Baptiste Collette, LA. The primary goal of the project is to create and manage crevasses through the natural levee ridges of rivers and major distributary channels so that the natural land-building process can create emergent and submergent aquatic communities critical to the overall productivity of the deltaic systems. Monitoring of sediment diversions will help to determine the management of the crevasses.

Marsh management

In marsh management projects, structures actively manipulate local hydrology to control water levels and salinity and while at the same time allowing ingress and egress of marine organisms. Marsh management plans generally incorporate existing canal spoil banks, the construction of short levees to connect these spoil banks, the installation of water control structures, and/or the construction of pump and other control structures to introduce fresh water into the managed area and keep out saline water. The main goals of marsh management are to minimize the loss of emergent and submergent plant communities by reducing salinities, stabilizing water levels, and restricting tidal exchange. Monitoring of marsh management projects will help determine operation schedules for pumps and structures.

Sediment and nutrient trapping

Sediment and nutrient trapping projects use structural devices such as brush fences or earthen berms to reduce wave energies, promote the deposition of suspended sediments, and increase water clarity. The goals are to reduce erosion of windward marsh edges, promote the growth of emergent vegetation, and increase the overall productivity of the area. Monitoring will help determine the effectiveness of different sediment and nutrient trapping techniques.

Project-Specific Goals

A critical step in establishing a successful monitoring program is to define the goals of conducting the monitoring. If the goals are poorly defined, there will be no guidance in the establishment of protocols. The CWPPRA requires an evaluation of the effectiveness of each project in achieving its specific goals directed towards creating, restoring, protecting, or enhancing coastal wetlands. For example, a project using dredged material may be built to reduce wave energies and consequent physical erosion or develop a new soil and sediment base at a proper elevation to restore or maintain vegetated marsh. Each of these projects begin with a hypothesis or set of hypotheses related to the expected change in physical, biological, or chemical variables of the project area. These hypotheses then guide the monitoring program as to which variables will be monitored and how frequently.

Control Areas

The importance of using appropriate control areas cannot be over emphasized. Monitoring on both project and control areas provides a means to achieve statistically valid comparisons, and is, therefore, the most effective means of evaluating project success.

Selection of a control area should ideally be done before project initiation. Controls should be ecologically similar to the project area yet located far enough away so as to not be influenced by the project. Potential control areas can be selected by use of WVA methods or through more basic comparisons of structural and functional attributes. To ensure the selection of appropriate controls, an interagency team of experts should be convened. If there is any question concerning the similarity of the control and project areas, more than one control area should be selected.

It is recognized that in many areas of Louisiana, appropriate controls cannot be identified. In addition, the extent of wetland modification (both planned and unplanned) occurring in this region often results in the loss of control areas before monitoring efforts are completed. We also recognize that occasionally, especially in the case of very large projects (e.g., sediment diversions and freshwater diversions from the Mississippi River or watershed projects) it may be difficult to select control areas that adequately reflect the same marsh type and function as those being affected by the project. In these cases, two strategies could be adopted:

(1) Monitoring before and after project implementation. The disadvantages of this strategy include delay in project implementation, temporal variability, and the inability to clearly identify cumulative impacts of the project in comparison to unaffected areas. In addition, before and after monitoring cannot ensure that the same events are being monitored for comparison; therefore, interpretation of the results will be difficult. However, such monitoring would provide some indication of project performance and impact.

(2) Baseline data collection. This may be especially important in areas where controls cannot be selected for monitoring. As a "once only" data collection program, it would not delay project implementation as much as full-scale monitoring before implementation (as in (1) above). It would provide a datum against which changing biological variables could be compared. In some cases, existing data bases might be considered appropriate as baseline data. If this were to occur, an interagency team of experts or their scientific advisors should be convened to evaluate the suitability of the existing data bases for this purpose.

Although before and after monitoring and baseline data collection provide valuable information, they do not necessarily provide a statistically valid evaluation of projects.

Statistical Design

The size of the project area, the number of different habitats present, and the heterogeneity within those habitats should define the number of statistical strata necessary for an analysis.

Before sampling is initiated, it is important to determine the desired statistical power for the analysis (Fairweather 1991). This procedure involves using a variance estimate to calculate the number of samples required to detect a percentage difference between two means. Initially, the sample size required to achieve this power can be estimated from sample variances reported in the literature, and these estimates can be refined by using data collected in the control area selection process. It should be recognized that this power will often improve with the use of data transformations and more complex analysis of variance (ANOVA) designs.

Data analysis for a project may include a two-way ANOVA with area and habitat as main effects. In the most basic design, the null hypothesis to be tested is whether the mean value for some variable is equal between the project area and the control area(s) or between the pre-project and post-project condition. The alternate hypothesis should be whether the mean value for that variable at the project area is greater or less than in control areas or whether the pre-project condition is greater or less than the post-project condition. It is important to determine whether the mean value for the variable increased or decreased because of the project, taking into consideration other outside influences. If the alternate hypothesis is limited to only whether the variable increased, negative effects will be indistinguishable from no effects.

Wetland Value Assessment Methodology

The Wetland Value Assessment (WVA) methodology was developed as a uniform and quantitative habitat-based assessment methodology for use in prioritizing project proposals submitted for funding under the CWPPRA. The WVA quantifies changes in wetlands quality and quantity that are expected from a proposed project.

The WVA was developed by the environmental work group assembled under the Planning and Evaluation Subcommittee of the CWPPRA Technical Committee. It is strictly designed for use in ranking proposed CWPPRA projects, and it is not intended to provide a detailed, comprehensive methodology for establishing baseline conditions within a project area. In addition, it was developed for application to the following coastal Louisiana wetland types: fresh marsh (including intermediate marsh), brackish marsh, saline marsh, and cypress-tupelo swamp.

The WVA operates under the assumptions that optimal conditions for a coastal wetland can be characterized, and that any existing or predicted condition can be compared to that optimum to provide an index of wetland quality. The quality component of a wetland is estimated or expressed through the use of a mathematical model developed specifically for each wetland type. Each model consists of 1) a set of variables that are considered important in characterizing the particular wetland type, 2) a suitability index graph for each variable, which defines the assumed relationship between wetland quality and the variable, and 3) a mathematical formula that combines the quality value (habitat suitability index or HSI) for each variable into a single value for overall wetland quality.

The variables chosen to describe wetland quality in each of the marsh types are

- V_1 - Percent of wetland covered by persistent emergent vegetation;
- V_2 - Percent of open water area dominated by aquatic vegetation;
- V_3 - Marsh edge and interspersion;
- V_4 - Water duration in relation to marsh surface;
- V_5 - Open water depth in relation to marsh surface;
- V_6 - Mean high salinity during the growing season; and
- V_7 - Aquatic organism access.

Predictions are then made as to how these model variables will change through time under two scenarios: with the proposed project in place and without the proposed project. A numerical representation of habitat quantity and quality is derived and compared between the two scenarios. Net benefits attributable to the project can then be compared to the net benefits from other projects in order to rank all proposed projects.

In most instances, variables measured in the monitoring program will provide data that can be used in the WVA models. Post-project WVA analyses utilizing these data can be compared with the results of WVA scores derived during priority project rankings in order to verify or refine the WVA. Such comparisons should not be used to judge project success or failure in achieving goals.

The monitoring work group recognizes the WVA as a planning tool and is therefore looking beyond the WVA in terms of monitoring variables. However, the WVA process can provide invaluable baseline information that may aid in the development of project-specific monitoring plans and/or the selection of appropriate control areas.

IV. APPROACH

The monitoring work group developed a broad-based, standardized approach for monitoring different variables. Each technical expert was asked to assemble a subgroup in order to

1) identify variables
2) develop a standard method or protocol for measuring each variable;
3) develop options for accurately and reliably measuring that variable over time;
4) develop options for accurately and reliably measuring that variable over space;
5) determine how the protocol, time, or space sampling might differ for each of the nine types of projects;
6) address a plan for statistical review;
7) address quality assurances;

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IV. INTRODUCTION

The charge to the water quality monitoring subgroup was to develop a protocol documenting the approach the monitoring work group should use in establishing a water quality monitoring design. This design will provide data for the assessment of the different types of restoration projects on area water quality, and yet be consistent enough to allow for comparison of data between projects. The monitoring design must consider possible water quality effects on waters receiving discharge from restoration projects. The subgroup also felt that the protocol should be flexible in design to allow for successful monitoring of the many different types of restoration projects that will likely be attempted. It should be emphasized that many of the topics addressed by the water quality subgroup are directly related to the charges assigned to the hydrology, vegetative, and soil and sediment subgroups. Our subgroup recognizes the potential of fecal bacterial contamination by some CWPPRA projects; however, active monitoring programs by the Louisiana Departments of Health and Hospitals and Environmental Quality already address this issue. Frequency and intensity of collection of data for monitoring water quality are directly related to or influenced by the needs of these other subgroups.

V. GENERAL DISCUSSION

Pre-project Selection Considerations

The first recommendations of the water quality subgroup are that prior to actual selection of projects, the CWPPRA Planning and Evaluation Subcommittee must consider and perform the following tasks for each possible project:

Table 3. Recommended prioritization of water quality variables for CWPPRA.

Project type	Salinity/ temperature	Physical, dissolved oxygen, pH, specific conductance	Nutrients, nitrogen, phosphorus	Trace metals	Synthetic organic compounds	Soil/suspended sediment			
						Nutrients	Trace metals	Synthetic organics	Size fraction analyses
Freshwater introduction and diversion	1[a]	2	2	4,2[b]	4,2	4,2	4,2	4,2	3,N
Sediment diversion	4	4	3	4	4	2	3	3	2,N
Marsh management	1	2	2	4,2	4,2	3	4	4	4,N
Hydrologic restoration	1	2	2	2,4	2,4	3	4	4	4,N
Beneficial use of dredged material	4	4	4,1	4,1	4,1	2	3,1	3,1	2,N
Shoreline protection	4	4	4	4	4	4	4	4	N
Barrier island restoration	4	4	4,1	4,1	4,1	2	3,1	3,1	2,N
Vegetative plantings	1	3	3	4	4	2	3,2	3,2	3,N
Sediment and nutrient trapping	3	3	1	4,1	4,1	2	3,2	3,2	3,N

[a]Priorities:

1 = Primary objective
2 = Secondary objective
3 = Tertiary objective - long term evaluation
4 = Lower priority - long term evaluation
N = As needed, unique to a specific project

[b]For columns that have two numbers listed, the first number indicates the priority of that variable(s) for projects where information for tasks 1-6 are available. The second number indicates the priority of the monitoring task for projects lacking information for tasks 1-6.

Grouping of variables	Instrument	Cost	Frequency of record	Environment
Other physical measurements-pH, dissolved oxygen, specific conductance, ORP (oxidation reduction potential), turbidity	Data collection platform	\$20k instrumentation, \$2-4k installation[a], \$6-8k maintenance	5-30 min	Highly variable, tidal areas
	Fixed recorder paper punch or digital recorder	\$4-8 maintenance	5-30 min	Highly variable, tidal areas
	Non-fixed data sonde (Hydrolab)	\$4-6k	5 min-2 hr	Highly variable, tidal situations, remote areas

[a]Installation cost if platform and transmitter are already installed.

These methods need quality control and assurance information in the form of duplicate samples, calibration checks, standards, and field checks. Dissolved oxygen probes may need frequent servicing during certain seasons to prevent biofouling.

Grouping of variables	Instrument	Cost	Frequency of record	Environment
Nutrients: total and dissolved nitrogen spp, phosphorus spp, (ortho P, NH_4, NO_2, NO_3, Organic)	Fixed sampler requires chilling to 4°C	\$20k instrumentation, \$10-35k including analysis	1 hr - daily	Highly variable, tidal situations
	Fixed probes for NH_4, NO_3	\$8-20k instrumentation, \$2-3k installation[a], \$3-4k maintenance, including analysis	5-15 min	Highly variable, tidal situations, nutrient-sensitive areas
	Daily observer	\$8k-collection and analysis	Daily	Stable areas

[a]Installation cost if platform and transmitter already installed.

Costs of monitoring can be greatly decreased by employing gas chromatograph-flame ionization scans for those compounds extractable with methylene chloride, and by using portable gas chromatographs for volatile organic compounds and immuno-assay kits for triazine herbicides. Confirmation of detections by any of these methods must be performed by using quantitative gas percent recoveries for the compounds analyzed.

Grouping of variables	Instrument	Cost	Frequency of record	Environment
Soils/sediment nutrients	Instantaneous, includes collection and analysis	$200	NA	NA

All samples should be chilled to 4°C immediately upon collection. Samples should be analyzed according to accepted methods. Quality control and assurance information need to be collected including duplicate analyses and laboratory standard and blank information.

Grouping of variables	Instrument	Cost	Frequency of record	Environment
Soils/sediment trace metals	Instantaneous, includes collection and analysis	$400-1,400[a]	NA	NA

[a] Cost is per sample. Cost of sample analysis is dependent upon the number and kinds of elements requested and the amount of ancillary data (TOC, grain size, surface area, etc.) needed.

Samples need to be chilled at the time of collection. Holding times are less critical; however, possibility for sample contamination is much greater. Analyses should be done according to accepted methods. This grouping of variables needs quality control and assurance information in the form of duplicate samples, and spikes and blanks from the laboratory.

Table 4. Sampling frequency and priority of variables.

Project type	Salinity/ temperature	Physical, dissolved oxygen, pH, specific conductance	Nutrients, nitrogen, phosphorus	Trace metals	Synthetic organic compounds	Soil/suspended sediment			
						Nutrients	Trace metals	Synthetic organics	Size fraction analyses
Freshwater introduction and diversion	R[a]	R2[b]	I2N	I4,2N	I4,2N	I4,2	I4,2N	I4,2N	I3N
Sediment diversion	4N	4N	I3N	I4,2N	I4,2N	I2N	I3N	I3N	I2N
Marsh management	R	R2N	I2N	I4,2N	I4,2N	I3N	I4N	I4N	I4N
Hydrologic restoration	R	R2N	I2N	I2,4N	I2,4N	I3N	I4N	I4N	I4N
Beneficial use of dredged material	I4	I4	I4,1N	I4,1N	I4,1N	I2N	I3,1N	I3,1N	I2N
Shoreline protection	I4N	I4N	I4N	I4N	I4N	I4N	I4N	I4N	N
Barrier island restoration	I4N	I4N	I4N	I4N	I4N	I2N	I3N	I3N	I2
Vegetative plantings	I1	I3N	I3	I4	I4	I2	I3,2	I3,2	I3
Sediment and nutrient trapping	I3	I3	I1	I4,1	I4,1	I2	I3,2	I3,2	I3

[a]Frequency of collection
I = Instantaneous
R = Realtime

[b]Priorities:
1 = Primary objective
2 = Secondary objective
3 = Tertiary objective - long term evaluation
4 = Lower priority - long term evaluation
N = As needed, unique to a specific project

Shoreline Protection

These kinds of projects are not expected to have any impacts on water quality; however, specific projects may require chemical samples from water and sediments before and after the project is completed.

Barrier Islands

These kinds of projects are not expected to have any impacts on water quality; however, specific projects may require chemical samples from water and sediments before and after the project is completed.

Vegetative Plantings

The water quality monitoring subgroup recommends that an initial synoptic sampling of the project area be completed (unless recent historical data exists) prior to initiation of the project. Sampling, especially soil and sediments, is recommended if problems are observed in the growth of the targeted plant species. Areas receiving agricultural runoff, especially herbicides, may need seasonally targeted sampling to determine factors effecting the success of the project.

Sediment and Nutrient Trapping

The water quality monitoring subgroup recommends that an initial synoptic sampling of the project area be completed (unless recent historical data exists) prior to initiation of the project. Additional yearly samples may be required to determine the effectiveness of an individual project. It should be noted that only those compounds identified during the initial synoptic sampling need to be reanalyzed.

VII. HISTORICAL DATA

Inventory of Existing Data

Maps and an inventory of current and historical U.S. Geological Survey (USGS) chemical and monitoring sites are on file with the monitoring work group. Nutrients, trace metals, pesticides, PCB's, and major ions in water and nutrients, trace metals, pesticides, and PCB's in sediments have been collected at most of the sites plotted on the map. Many of the current sites have suspended sediment and discharge collected on routine basis. Volatile organic compounds (VOCs), triazine herbicides, and semi-volatile priority pollutant data have not been collected at any USGS sites with the exception of the Mississippi, Calcasieu, and Mermentau Rivers.

A listing of the Louisiana Department of Environmental Quality (LDEQ) water quality stations also is on file with the monitoring work group. The LDEQ does not analyze for synthetic organic compounds on a routine basis at any of their sites with the exception of VOC's on the Mississippi River. The LDEQ does have synthetic organic compound data for the Calcasieu River system.

A listing of all stations in the U.S. Environmental Protection Agency STORET system also is on file with the monitoring work group. A total of 2,922 stations are listed for the Louisiana coast and inland to Interstate 10.

A listing of all USACE water quality sites is available from the water quality monitoring subgroup.

Also on file with the monitoring work group is a listing of all current RCRA and CERCLA sites in Louisiana. As previously stated, location of these sites should be considered by the CWPPRA Planning and Evaluation Work Group prior to project selection.

Potential Upgrading of Existing Sites

All federal agencies should be willing to increase the variables at existing sites to meet the needs of specific restoration projects if funds are provided to cover the additional costs of collection and analyses.

VIII. DATA STORAGE

The water quality monitoring subgroup recommends that all agencies that collect water quality data store that data electronically, review it for quality control prior to entry into data storage systems, enter data in a timely fashion, and have the capability of transferring data to the appropriate agencies.

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IV. INTRODUCTION

The primary purpose of hydrologic monitoring is to collect data required for the scientific evaluation of completed projects. In this evaluation, the success of a completed project will be measured by the number of acres of wetlands saved or created. This effort is intended by all involved—Federal, State, and local governments and private citizens alike—to be successful and have a positive, lasting effect in coastal Louisiana and to either preserve or create a measurable impact on our marshes and coastline. To measure the degree to which these activities and projects are being successful, physical variables must be quantified in the beginning, during construction, after completion, and for posterity. These variables will define the problem, define human impact, measure progress, suggest midcourse changes, improve design and performance of future projects, and ultimately justify our efforts and direction.

indicators of hydrologic conditions in a wetland, of seasonal flooding, and of extreme events such as floods and hurricanes. They are indicators of tidal exchanges and sea-level change. Water-level data are important in interpreting aerial photography and converting bathymetric and topographic data to a sediment deposition, subaqueous delta development, and scour. Bathymetry can also provide valuable information on water depths, location of channels and crevasses, and overall marsh bottom configuration that will affect different hydrologic measurement and management practices.

Topography

Topography can be used in conjunction with aerial photography in quantifying increases and decreases in wetland areas and barrier islands. The elevation of the ground in a wetland affects the type of vegetation present and the depth and duration of water. Topography can be used to measure sediment deposition, subaerial deltaic development, and subsidence. Topography can also provide valuable information on channel obstructions, natural and artificial banks and levees, and points of ingress and egress.

Salinity

It is important to quantify the salinity in a project area because of its influence on wetland habitat. Wetland habitats are characterized by salinity levels, i.e., fresh marsh and saline marsh. Saltwater intrusion is a major cause of loss of freshwater wetland habitat in areas such as the Mississippi River delta because of its adverse impact on freshwater vegetation. Project types such as marsh management, freshwater diversion, and hydrologic restoration are geared toward regulation of salinity levels in a project area to reduce wetland loss.

The main body of information on this variable can be found in the report on water quality monitoring.

Discharge, Velocity, and Direction

Discharge, velocity, and direction data are important in defining circulation patterns and tidal characteristics within a project area. Circulation affects the presence and variability of nutrients in a wetland; estuarine organisms; and turbidity, salinity, and other water quality variables. Water exchange is an important variable in the quality of cypress-tupelo swamps. Discharge can be correlated with suspended sediment to quantify the amount of sediment available for deposition. Discharge measurements can be used to "rate" a structure to determine the volume of flow entering or exiting a water control structure, such as freshwater diversion or hydrologic restoration structures given certain headwater and tailwater conditions. Velocity and direction data can assist refuge managers in determining when to open or close a structure and for how long.

independent auxiliary datum references used to verify or reestablish the gauge datum. All gauges should be periodically checked by running levels or GPS and by using the reference marks to maintain a fixed datum.

A common datum for all the gauges in the coastal zone would be beneficial. A common datum allows for the comparison of data within the project area and throughout the coastal zone. However, this may prove to be cost prohibitive or infeasible. Reference marks may use a common datum such as NGVD but will contain different adjustments to the datum.

The costs to establish a datum for a water-level gauge has not been included in the cost of the gauge presented in this report. Costs will vary depending on the location of the gauge. A baseline of levels has been established by the U.S. Army Corps of Engineers (USACE) along the Mississippi River into Southwest Pass. Levels have also been run for the Lower Atchafalaya River. To tie into these baselines may be expensive; the cost of the Mississippi River levels was $40,000 for 20 miles of levels. GPS has been used in the Lake Verret-Atchafalaya area very successfully. The field work and post processing costs were approximately $26,000. More than 10 gauge datums were verified with the GPS method; the cost per gauge is therefore reasonable. In using GPS, consideration should be given to grouping gauges in a geographical area to reduce costs.

Ongoing Programs

The USACE has a gauging program to evaluate the effectiveness of their projects. The gauges are located predominantly along rivers, channels, and bayous. The networks, type of gauge, and parameters measured were designed for projects such as navigation, flood control, and water supply. Because many of the gauges are continuous recording or realtime, they can provide valuable information for the CWPPRA projects in the vicinity. Use of USACE gauges can minimize the cost of the CWPPRA monitoring program.

The USACE also installs gauges for data collection during the design phase of their projects. Although the data collection is short term and often uses an arbitrary datum, it can provide information on pre-project conditions in the coastal zone.

The USACE and U.S. Geological Survey (USGS) have a cooperative stream-gauging program with many gauges in the coastal zone. Again, the gauges are located predominantly along rivers, channels, and bayous and were installed mainly for flood control purposes.

The USGS and the Louisiana Department of Natural Resources have a cooperative program to monitor state wetland restoration projects in the coastal zone. The collection of stage, precipitation, salinity, wind speed and direction, and velocity data are primarily in realtime.

The U.S. Fish and Wildlife Service has installed some gauges in several of their refuge areas to monitor water levels, salinity, and tidal characteristics. The gauges collect realtime data.

The National Ocean Survey and the National Geodetic Survey have placed tide recorders and related equipment in the coastal zone. Data from these equipment are available to establish base conditions in some projects locations.

Data protocols are usually in ASCII format or are convertible to ASCII. The use of these data will minimize costs to establish base conditions and monitor project hydrology.

VI. METHODOLOGY

Precipitation

Precipitation is measured on the basis of the vertical depth of water that would accumulate on a level surface if the precipitation remained where it fell. Recording precipitation gauges are recommended when continuous records of precipitation are required. The tipping bucket continuous recording gauge is used with Handar equipment for realtime transmission. Other recording gauges include the weighing type gauge and the float type gauge. Precipitation is accrued on an hourly or more frequent basis until the gauge is reset. Standard rain gauges are used when continuous records are not required. These gauges need to be read daily and emptied. Precipitation is reported on a daily basis. The units of measure for precipitation data are generally inches.

Precipitation measurements are subject to various errors. Individually, the errors are small but cumulatively they could be significant. Errors are smaller for standard rain gauges than recording gauges. In rainfall of 5-6 inches per hour, the bucket of a tipping bucket gauge tips every 6-7 seconds. About 0.3 seconds is required to complete the tip, during which some water is still pouring into the already filled compartment. The resulting recorded rate may be 5 percent too low; however, the water is all caught in the gauge reservoir and can be measured independently of the recorder. The difference can be prorated through the period of excessive rainfall. The most serious error is the deficiency of measurements caused by wind; consequently, wind shields are recommended to reduce the error.

Methodology recommended for a project will depend on the uses for which the precipitation data are intended and the site at which the gauge will be located. Where accumulated volume of overland flow is of interest, the depth of rainfall measured by standard rain gauges should be adequate if the site is accessible on a daily basis. Recording precipitation gauges reduce the need for daily visits and can be serviced during the project site visits. Recording gauges also provide hourly or more frequent data. The use of tipping bucket gauges takes advantage of the Handar equipment used to transmit other hydrologic variables in realtime. For high priority projects, the standard protocol recommended is the use of tipping bucket gauges at water level or water quality sampling sites. This practice allows for continuous data collection and realtime transmission. The cost of a Handar 444a tipping bucket rain gauge is low, about $800. Installation costs are included in the cost of installing the other equipment. Data of good quality can be obtained by establishing a system of quality control that includes not only periodic inspection of stations and maintenance or repair of equipment, but preliminary checking of data by internal consistency checks. Maintenance costs should be no more than $500 per year, including analysis of the data for quality control.

Precipitation should be recorded continuously by using the same recording periods as the National Weather Service. Hourly incremental precipitation data can be determined from the data collected. Monthly and annual totals can be computed from the data with adjustments for periods of high intensity.

The uses for which the precipitation data are intended should determine network density. A relatively sparse network of stations would suffice for determining annual averages over large areas. In general, sampling errors, in terms of depth, tend to increase with increasing areal mean precipitation and decrease with increasing network density, duration of precipitation, and size of area. Average errors tend to be greater for summer than for winter precipitation because of the greater spatial variability. The minimum density of precipitation network recommended for general hydrometeorological purposes for flat regions of tropical zones is 230-350 mi^2 per station.
For lower priority projects, records from nearby precipitation stations may be sufficient. Gauges should be added, if necessary, to achieve a good spatial density. The cost to purchase and install a recording rain gauge is approximately $1,400 with maintenance costs around $1,000. Tipping bucket gauges can also be installed at existing realtime stage recording sites; the cost to purchase and install this equipment is approximately $800 for the gauge and $1,000 to install. Maintenance costs should be no more than $500 per year but will include some analysis of the data for quality control.

Evaporation

The pan is the most widely used evaporation instrument. The operation of a pan station is relatively inexpensive and should provide good estimates of annual evaporation. Water levels in the pan are measured, and the evaporation, in inches, is computed as the difference between observed levels, adjusted for any precipitation recorded. Three types of exposures are employed for pan installation: sunken, floating, and surface. Burying the pan tends to eliminate boundary effects such as radiation on the side walls and heat exchange between the atmosphere and the pan, but causes observational problems.

In the coastal zone, there are currently no evaporation pans from which evaporation rates can be determined. For projects where precipitation and evaporation are high priorities, one evaporation pan should be installed in the hydrologic basin along with a precipitation gauge for continuous data collection and realtime transmission. Purchase costs will be approximately $800 for the pan. Installation and maintenance costs will be included in the cost of the precipitation gauge.

Evaporation should be recorded continuously by using the same recording periods as the National Weather Service. Annual, seasonal, and monthly evaporation rates can be determined from the data collected. One evaporation pan per hydrologic basin should be sufficient spatial density.

Wind Speed and Direction

Wind speed is measured with anemometers. Both cup and propeller anemometers are commonly used. A wind vane measures the direction from which the wind is blowing. Surface winds are generally reported in miles per hour, meters per second, or knots. Surface wind directions are generally reported in degrees to the nearest 10 degrees.

Reported wind speed above 3 kn is nominally accurate to plus or minus 1.5 kn under steady-state conditions. Wind vanes are constructed to indicate direction within plus or minus 5 degrees.

Ideally, surface-wind sensing equipment should be placed 20 ft above the ground on a freely exposed tower over terrain that is relatively level and free from obstructions to wind flow.

For high-priority projects, the standard protocol recommended is to use automatic wind-speed and direction equipment linked to the Handar communication equipment for realtime data collection. Wind-speed and direction equipment would be installed at each water level and water quality data collection station with a data collection platform. The advantages are continuous realtime collection of data and reduced maintenance costs of on-site equipment. This protocol is really the only effective way to measure data of this type. Cost to purchase the equipment is about $600. Installation costs are included in the cost for a water-level or water-quality gauge. Maintenance of wind equipment should be performed at specified intervals to ensure continuity of data to prevent malfunctions. Maintenance costs should be no more than $500 per year. Maintenance costs include some analysis of the data for quality control.

The recommended frequency for wind-speed and direction data collection is continuous. In many cases, the dynamics of the wind data may be more important than the actual data. The same reporting periods at the National Weather Service--hourly, daily and monthly summations--should be adopted.

Spatial distribution of wind-speed and direction equipment will be dependent on the use of the data collected and the complexity of the project area. As data collection efforts move east across the coastal zone, wind data become more important. Wind gauges are important in the Barataria Bay, Breton Sound, Atchafalaya floodway, and Lake Pontchartrain hydrologic basins. Wind gauges should be distributed closer than a 50-mi radius in these basins because large-scale wind cells and circulation patterns develop in them. Wind gauges become less important in the Terrebonne and Teche-Vermilion river basins, and are generally not important in the Mermentau and Calcasieu-Sabine river basins. Because land breezes are different from sea breezes, data at airports should be only cautiously used in the coastal zone. Fewer wind gauges are needed if the data are to be used in conjunction with a wind-field model.

Where data collection is a lower priority, continuous records from a second site within a 40-mi radius are sufficient if this second site has similar hydrologic and hydraulic characteristics. Wind-speed and direction gauges should be installed at existing realtime stage recording sites to achieve a good spatial distribution. The purchase and installation costs at each site are approximately $600 to purchase and $500 to install, but installation costs will be lower where precipitation gauges are also installed. Maintenance costs should be no more than $500 per year, including analysis of the data for quality control. Purchase and installation of recording wind gauges without realtime capabilities should cost approximately $3,600. Maintenance costs should be no more than $1,000 per year.

Water Level

Stage is a measure of water-level surface in a body of water. Stage can be measured discretely or continuously over a period of time. Depending on the measurement device, accuracy limitations will range from 0.01 to 0.1 ft.

Stage measurements can be made by using several different devices. A staff gauge is the simplest of stage measurement devices. Water-level measurements are made by visual inspection of a vertical graduated staff. Water-level measurements can also be measured with a continuous stage recorder. The water levels are determined by using a tape-float system or pressure transducer. Readings are recorded on a regular time interval on digital recorders, graphic recorders, or electronic data recorders. Electronic data recorders are devices such as basic data recorders where the stage values are stored in memory and downloaded into a computer during field inspections or into data collection platforms that transmit the data via satellite, radio, or telephone on a realtime basis.

Stage recorders can be temporary or built to last over a long period of time and under various environmental and climatological conditions. Cost can range from $200 for a staff gauge to $20,000 for some data collection platforms. Some of this equipment can be rented.

Where cost is not a major issue and where water-level data are a high priority variable data collection platforms are recommended as the standard protocol. Data collection platforms have a high equipment and installation cost for the stage recorders but reduce the cost of collecting other variables such as water temperature, dissolved oxygen, and precipitation because the equipment that measures the other variables can also use the data collection platform. Data collection platforms reduce maintenance costs; maintenance personnel can see when a gauge is not functioning properly and can perform maintenance on a less frequent basis than without the data collection platform. Because maintenance is performed immediately rather than on a scheduled basis, periods of bad or missing data are reduced. Equipment costs will be $5,000 and installation costs $3,000. Maintenance costs will range from $3,000 to $6,000 per year ($5,000 will be used for estimating purposes), including analysis of the data for quality control.
The measurement of stage over time can be from one reading at a site to whatever interval is required, such as daily, hourly, or less over a determined period.

Measurement of stage at one location can be compared to other water levels within a certain range of the gauge in common hydrologic areas. Spatial distribution of water level gauges will depend on the project type and the hydrologic characteristics of the project area.

At many project areas, existing stage recorders or realtime data collection platforms in the vicinity will suffice. At some locations, an observer may be hired to daily record stage from a staff gauge; a paid observer usually receives about $365 per year. Purchase and installation of the staff gauge would be about $1,100, with annual maintenance costs about $500 per year. Some sites can be monitored continuously for a short time, i.e., 30 to 180 days to determine the relationship of stage at the project to a nearby permanent location. Other sites can have a staff gauge installed, which would be read during the site visits. Purchase and installation would be approximately $1,100. These protocols are best suited for projects where collection of water-level data is a low priority.

There will be some projects where the level of the water is not as important as the forces of the waves and littoral transport. Directional wave gauges may be necessary to determine these forces. Wave gauges are placed in deep and shallow water near the area of interest. Data are gathered for a 2-3 year period and used to develop a wave model. The wave model predicts the near-shore wave climate based on the deep water wave gauge data. The model then replaces the shallow water gauges. Wave gauges cost about $20,000 each. Installation and maintenance costs are similar to the realtime data collection platforms.

The National Oceanic and Atmospheric Administration (NOAA) has several wave gauging stations in the Gulf of Mexico as do many of the oil companies. Use of these gauging stations may be more reliable and less expensive than installing additional deep water gauges.

Bathymetry

Bathymetric surveying is the measurement of depths of water bodies. Bathymetry is generally measured from a boat by using positioning equipment and a fathometer. Range lines are laid out to be surveyed on a routine basis. Positioning is usually recorded in x-y coordinates; depth is recorded in feet. Data can be recorded electronically and even transmitted over telephone hookups.

Costs for bathymetry data collection will vary according to the size of the area to be surveyed and the depth of water. Some shallower water bodies may have to be surveyed by using topographic land surveying techniques. Costs will also depend on desired survey accuracy. Costs for a bathymetric survey have been included in the costs for a topographic survey because most of the project sites will probably require a combination of the two types.

For projects where this variable is a high priority, bathymetry should be measured once before project implementation and at least once during each 3-year reporting period. Frequency, methodology, and survey coverage will be project and priority dependent. Spot elevations should be taken annually in conjunction with aerial photography to provide supplemental information.

Topography

Topographic surveying is the measurement of the elevation of land. Topographic surveys can be taken by using three different methods. (1) A surveyor can "walk" an area, recording horizontal location and vertical elevation. A survey that uses the water surface as a base and measures elevations with a rod is less expensive than a survey that uses positioning equipment and a fathometer. The accuracy of such a survey is about 0.5-1.0 ft. (2) Surveying with GPS equipment should be used when some error in measurement is acceptable. With GPS equipment, the use of range lines to determine location is unnecessary. Data can be recorded electronically. (3) Conventional equipment is used when horizontal and vertical accuracy is critical. Range lines are laid out to be surveyed on a routine basis. Positioning is usually recorded in x-y coordinates; depth is recorded in feet.

Costs for topographic surveying will vary according to the size of the area to be surveyed, its accessibility, and the ground conditions. Survey costs can range from $5,000-$10,000 per square mile for a "rod" survey or GPS type survey, to $30,000-$60,000 per square mile for a conventional survey. Depending on the project area characteristics and the presence of permanent bench marks, these costs could be double or higher.

For projects where the magnitude of yearly accretion on an existing wetland is measured in millimeters, traditional topographic surveying techniques are not suitable. Three different methods can be used to measure accretion of this type. First of all, soil cores can be taken to determine mineral contents. Generally, the presence of minerals in an organic layer indicate accretion. Second, direct measurement can be made by using feldspar marker horizons at intervals from the edge of streambanks. Soil cores are taken to measure accretion. Problems can arise with this method if the existing surface is porous and spongy; the feldspar can diffuse through a zone for several centimeters. A third method is the use of experimental sediment trapping devices. Problems can arise with animals digging in the vicinity of the traps and throwing additional sediment into the traps. All three methods were used in a recently completed monitoring program for a small-scale freshwater diversion project on the Mississippi River. This type of topographic monitoring would also be suitable for a vegetative planting, marsh management, sediment trapping, and hydrologic restoration projects. Costs for the materials and evaluation of the cores should be less than $1,000 per year. During the site visits, cores could be taken and sediment traps emptied.

For projects such as sediment diversion, barrier island restoration, dredged material, and shoreline protection, where this variable is a high priority, topographic surveys should be taken once before project implementation and at least once during the 3-year reporting period. Frequency, methodology, and survey coverage will be project and priority dependent. Spot elevations should be taken annually in conjunction with aerial photography to provide supplemental information. For the other project types, measuring accretion by using soil cores, feldspar marker horizons, and sediment trapping devices is recommended.

Salinity

Salinity is a measure of dissolved mineral in sea water in units of parts per thousand. Salinity is typically measured by using electric resistance meters.

Water samples can be collected on a regular basis and analyzed for some projects. Recording salinity or conductivity meters can be installed on those projects needing frequent salinity data.

There are water-level gauges such as the Endeco 1159 that also measure temperature and salinity in addition to stage. Hydrolab H_2O equipment is another gauge that measures all three variables. Both can be used with data collection platforms. Costs for the equipment vary between $8,700 and $10,500. Maintenance costs should be around $2,000 per year. Where water level, salinity, and water temperature are high priorities, this is the recommended standard protocol. The advantages are the ability to acquire realtime data in hourly increments. The disadvantage is mainly in the cost of the equipment. In fresh and intermediate marshes, salinity levels in the growing season, from March through November, are important. In the interests of cost, monitoring could be realtime during the growing season and monthly for the remainder of the year.

Where salinity is a lower priority, monthly collection is recommended in conjunction with site visits. Salinity can be measured during the site visits by using a field instrument such as a YSI 3800, which measures water temperature, salinity, and dissolved oxygen, among other things. The cost of this equipment is about $5,000. Existing data collection platform equipment can also be upgraded to measure and record salinity. Purchase and installation costs will be about $3,100. Maintenance costs should be no more than $500. Further information on methodology, recommended protocol, cost, and frequency of data collection can be found in the water quality monitoring subgroup report.

Discharge, Velocity, and Direction

Discharge is the measurement of volume of water passing a given point within a given period of time. Units of measurement for discharge are typically cubic feet per second.

To determine discharge, a measurement of velocity and cross-sectional area is necessary. Velocities are usually measured with mechanical velocity meters, electromagnetic velocity meters, and acoustical velocity meters. Some of these meters can measure only in one direction, while some can measure bi-direction, and others in any direction. The measurement of area is made with physical sounding of depth or by using electronic depth finders.

Discharge measurements are instantaneous measurements, that is, measured at one point in time. Some projects require that the discharge rate be known over a period of time. Typically, discharge over a period of time is determined by using a stage-discharge relationship. A series of discharge measurements is made at different stage elevations and a relationship between stage and discharge is determined. Unfortunately, this stage-discharge relationship does not apply to tide-affected areas. Another method to determine continuous discharge is to measure continuous velocity and to develop a relationship between velocity and discharge.

Discharge measurements are typically made from bridges, boats, or even by wading the channel. Discharge measurements typically cost around $800 for 20 measurements in small channels. Costs will vary depending on site location and hydrologic conditions.

Some projects need only velocity and direction measurements to determine the movement of water instead of the volume of water moved. Velocity and direction measurements can also be used to monitor the tidal inflow and outflow through gaps and openings in the barrier islands. Tides can transport sediments into and out of the barrier island area. Velocity and direction recorders that interface with the data collection platforms are available. This equipment costs around $5,100. Installation costs are around $500. Maintenance costs are approximately $4,000. Maintenance costs include the cost to compute discharge.

The standard protocol for data collection will vary with project type and location. For example, large scale uncontrolled diversions will require discharge measurements to be taken from a boat on a routine basis. Conventional measurements should be taken where cross-sectional geometry fluctuates and where the relation between velocity and discharge will vary over time. Velocity and direction measurements can be taken where the cross section does not appreciably change over time and where the direction of flow is more important than the volume of flow. Frequency and spatial distribution of discharge measurements will also be project dependent. Discharge measurements could be taken during the project visits.

Suspended Sediment

Sediment is solid material that originates mostly from disintegrated rocks and is transported by, suspended in, or deposited from water. It includes chemical and biochemical precipitates and decomposed organic material such as humus. Suspended sediment is the sediment that at any time is maintained in suspension by the upward components of turbulent currents or that exists in suspension as colloid. Suspended sediment is expressed in parts per million (ppm) or milligrams of dry sediment per liter of water sediment mixture (mg/L). Suspended sediment samples can be collected in several ways. In moving water, samples can be collected by using a number of different types of point samplers. Samples are collected at different points in a vertical profile and combined for analysis or analyzed individually. Suspended sediment samples can be collected in low velocities with wide-mouth samplers. Suspended sediment samples can also be collected by using a pump system to collect the sample. Automatic samplers are also available to provide unattended sampling at the frequency desired. Sediment sample costs will vary depending on the number of samples taken. A typical sampling program would cost about $1,800 for data collection and lab analysis of around 20 stations on small channels. A DH59 sampler costs about $500. Additional information is provided in the water quality monitoring subgroup report.

Where sediment sampling is a high priority, channel measurements taken with a point sampler should be made or an automatic sampler should be installed. Channel measurements generally require a discharge or velocity measurement for correlation. Automatic samplers require implementation of a good quality control system that includes routine visits for maintenance. The frequency of measurements will be project and site dependent. Sampling should be performed a minimum of six times per year. Sampling could be done during the site visits.

Groundwater

Probably the easiest technique to measure groundwater is to install a shallow piezometer at the same time soil cores are initially taken. The piezometer would be slotted PVC and would need some type of fine-gravel pack to minimize siltation, an upper casing, and a protective cap. Height of groundwater could be measured by using a simple ruler from the top of the casing during site visits, or any other data collection event.

Piezometers to monitor groundwater are relatively inexpensive; they cost a few hundred dollars each. Piezometer monitoring could be done during site visits or when personnel are in the field for other monitoring.

Piezometers can probably be installed at a cost of a $200 to $400 each. Actual monitoring costs will be minimal since the monitoring will occur during other visits to the project area and take only a few minutes. Data collation and analysis will also be minimal. Estimated costs are $5 for collection and $10 for collation, quality control, and analysis per piezometer.

Soil Salinity

Soil salinities can be measured by extracting interstitial water from a surface sediment sample by centrifuge. In many cases, freezing and defrosting a segment of sediment will disrupt sediment particle structure and allow settling. Separation of interstitial water can then be measured by a conductivity probe. Titration is accurate, but time consuming and therefore expensive in terms of labor. A refractometer is quick and inexpensive, but measurements are only accurate to approximately 1 ppt.

Soil salinities change slowly, and variation will be dampened compared to variation in salinity of the overlying water, which will change with tidal cycle as well as wind direction, seasonal changes to freshwater input, and climatic cycles. Thus soil salinities can be measured monthly for projects that rank this data collection a high priority, at least within the season when projects are most likely to affect salinity. For example, freshwater diversions are typically operated seasonally when fresh water is available and when biota are most sensitive to high salinity. When soil salinity monitoring is a medium priority, monitoring should be done monthly during times when projects are most likely to affect soil salinity. With those project types where soil salinity monitoring is a low priority, monitoring may be done infrequently or not at all.

Soil salinity samples can be collected with the soil-sediment sampling equipment and therefore will have no costs for initial sampling. Costs for analysis are unknown at this time. If annual soil samples are not collected, annual surface samples to determine soil salinity will cost about $10 to collect, assuming they are collected during some other monitoring event or a project visit.

If soil salinity sampling is coordinated with soil-sediment sampling, no additional equipment expense should be incurred. Cost of a conductivity probe for measuring salinity (e.g., a YSI 3800) is about $5,000.

VII. HYDROLOGIC DATA COLLECTION

Types of Projects Needing Hydrologic Monitoring

The monitoring work group has identified nine types of projects for which we are to develop hydrologic monitoring requirements. The types of projects are listed in Table 5 along with the priority of need for hydrologic monitoring. The priorities correspond to the four purposes of hydrologic monitoring discussed in the introduction of this report.

Table 5. Priority consensus of hydrologic monitoring projects.

Project type	Priority consensus
Freshwater diversion	1
Sediment diversion	1
Marsh management	1
Hydrologic restoration	1
Dredged material	4
Shoreline protection	4
Barrier island restoration	3
Vegetative plantings	2
Sediment and nutrient trapping	2

The hydrologic monitoring subgroup has further prioritized monitoring of variables within each project. Priorities agreed upon by subgroup members along with estimated costs are shown in Table 6.

Table 6. Monitoring matrix by priority[a] for hydrologic monitoring projects.

Project type	Precip.	Evap.	Wind speed direction	Water level	Bathymetry	Topography	Salinity	Discharge	Suspended sediment	Ground water	Soil salinity	Annual cost[b]
Freshwater diversion	1	3	1	1	3	3	1	1	1	4	4	$39,200
Sediment diversion	3	3	3	1	1	1	3	1	1	4	4	$46,200
Marsh management	1	3	1-3	1	2	2	1	2	3	4	2-3	$23,600
Hydrologic restoration	1	3	2-3	1	2	2	1	2	3	4	2-3	$24,100
Dredged material	4	4	4	3	1	1	4	4	4	4	1	$10,500
Shoreline protection	4	4	2[c]	3[d]	1	1	4	3	4	4	4	$6,000
Barrier island restoration	4	4	2[c]	3[d]	1	1	4	3	4	4	4	$11,000
Vegetative plantings	2	3	4	2-3	3	3	1	4	3	4	2-3	$8,000
Sediment and nutrient trapping	4	4	3	2-3	1	2	3	4	2-3	4	2-3	$33,100

[a]Key:
1 = Primary objective
2 = Secondary objective
3 = Tertiary objective (long term evaluation)
4 = Lowest objective (long term evaluation)

[b]Estimates include average annual equipment maintenance cost for one gauging station.

[c]Wind vectors may have a higher priority if needed to hindcast wave height and period.

[d]A directional wave gauge to determine the forces and littoral transport may have a high priority in determining failures.

VIII. HISTORICAL DATA

A table showing inventory of current and discontinued hydrologic data collection stations in Louisiana is on file with the monitoring work group. Equipment type varies, depending on location and the frequency of collection. Generally, realtime gauges use Handar GOES equipment. Water-level gauges may be electronic continuous recorders, strip charts, or bubbler gauges. Daily water levels are usually read from a staff gauge. Daily temperature and chloride data are from paid observers. Discharge measurements and sediment samples are taken 3-4 times per week to monthly from a boat; daily discharge and sediment loads are computed from rating curves. Lark rain gauges are used for hourly and daily rainfall records; standard rain gauges are used for daily records.

Maps showing the network of current hydrologic data collection stations in the Louisiana coastal zone, which can be incorporated into the hydrologic monitoring program are available from USACE.

Some of the realtime water-level stations can be upgraded with precipitation, salinity, water quality, velocity, and wind gauges. The cost to add a rain gauge is about $800 for the equipment, $1,000 for installation, and $500 per year for maintenance. Adding a wind-speed and direction gauge will cost around $600 for equipment, $1,000 for installation, and $500 per year for maintenance. A salinity upgrade will cost about $2,600 for equipment, $1,000 for installation, and $2,000 per year for maintenance. Temperature will also be measured with this equipment. The cost to add a velocity and direction gauge is about $5,000 for equipment, $1,000 for installation, and $1,000 per year for maintenance. Computing discharge from the velocity gauge will add about $3,000 per year to the annual maintenance costs for periodic discharge measurements and the computation of discharge. Adding water-quality probes, to determine aspects such as dissolved oxygen, would cost at least $5,000 for equipment, $1,000 for installation, and $3,000-$10,000 per year maintenance. All maintenance costs include analysis of data for quality control. Costs will vary on location and accessibility. Costs do not include replacement costs in the event of vandalism or theft.

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I. TITLE: MONITORING PROTOCOL FOR EXAMINATION OF THE IMPACTS OF CWPPRA PROJECTS ON SOIL DEVELOPMENT, SUBSIDENCE, AND MARSH ACCRETION

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All subgroup members provided valuable input to this document. In addition to those listed above, discussions with Wayne Hudnall, Department of Agronomy, Louisiana State University, and Lee Wilson, Lee Wilson and Associates, contributed to the development of the monitoring protocol.

IV. INTRODUCTION

Continued vertical development of marsh soils is critical to their survival in coastal Louisiana. Subsidence is recognized as one of the major processes causing coastal erosion and wetland loss. Subsidence of Mississippi deltaic plain and chenier plain sediments, combined with eustatic sea-level rise, has resulted in relative sea-level rise rates of over 1 cm/year in the delta plain and approximately 0.6 cm/year in the chenier plain (Penland and Ramsey 1990). If coastal marshes cannot increase surface elevation at the same rate as relative sea-level rise, marsh soils will become increasingly waterlogged. Chemical changes in the marsh soil resulting from such waterlogging can cause reduced growth and even die-back in wetland vegetation in both saline and fresh Louisiana coastal marshes (Koch et al. 1990). Insufficient accretion of the marsh surface to keep pace with relative sea-level rise is frequently termed a "sedimentation deficit."

The processes that contribute to accretion of the marsh surface can be summarized as follows:

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NVA = [Deposition on the marsh surface + belowground plant production] -
[erosion from the marsh surface + belowground decomposition].
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where NVA is net vertical accretion of the marsh surface. The processes that contribute to subsidence include geosynclinal downwarping, compaction of Pleistocene and Tertiary sediments, compaction of Holocene deposits, localized consolidation, tectonic activity, and fluid withdrawals. Consequently, the impact of projects implemented under the Coastal Wetlands Planning, Protection, and Restoration Act on marsh accretion and soil development can be dramatic in terms of their effect on depositional and erosional processes at the marsh surface and the production and decomposition of organic material within the soil, but rarely will the projects be able to impact the underlying causes of subsidence. However, the type of sediments composing the marsh soils, their grain size, and their chemical characteristics affect long-term stability, and these factors might also be impacted by projects aimed at marsh restoration. Therefore, we propose a monitoring plan that includes a broad spectrum of soil variables.

It is important to recognize that even if the stated goals of a particular project are achieved, there may be unintentional or indirect alterations to marsh ecosystem function that can have detrimental cumulative impacts on the ecosystem. Consequently, to fully evaluate the project it is necessary to monitor marsh soil variables other than those directly impacted by the project. Because of the delicate balance between marsh accretion and relative sea-level rise, it is important to monitor accretion in areas where accretionary processes are directly or indirectly impacted by the project, even if enhanced accretion is only a secondary goal for the project. For example, the stated goal of a marsh management project might be to increase vegetation growth, and this increased productivity may either increase or decrease net vertical accretion via its effect on organic accumulation, depending upon concomitant alterations in decomposition (see mass balance equation above). Monitoring of changes in soil type can also indicate the impact of vegetative or hydrologic changes on the stability and fertility of the soil substrate.

Some projects proposed for funding by CWPPRA do not involve the manipulation of marsh processes but seek instead to create marsh in areas where it does not now exist (e.g., projects on the beneficial use of dredged spoil or the back barrier marsh component of barrier island restoration). These projects aim to create marsh that functions naturally and can become self-sustaining in the long term. Given that these projects are developed in a subsiding coastal environment, natural accretionary processes (involving the accumulation of both organic and inorganic material) must occur or the marshes will be gradually submerged and the vegetation subjected to waterlogging. In addition, an important aspect of marsh creation is the development of soil properties. The newly created marsh soil must attain adequate hydrologic function to prevent waterlogging and/or the accumulation of toxics while providing the necessary nutrients for vegetative growth.

In those projects that aim to stimulate accretionary processes or recreate natural marsh development processes, e.g., sediment diversions, monitoring of marsh vertical accretion and changing soil properties is essential to assessing the success of the project. On the basis of this assessment of the need for monitoring of soil development and accretionary processes in a variety of types of project, the proposed CWPPRA projects can be classified as follows:

> Class A. Those that aim to create new marsh by artificial means (e.g., use of dredged spoil) but do not manipulate marsh processes, and where subsequent accretion and soil development are essential for the longevity of the project.
>
> Class B. Those in which the manipulation of accretionary processes is a minor or secondary aim of the project, but where indirect affects on accretion and changes in soil type might occur (e.g., freshwater diversion, marsh management).
>
> Class C. Those that specifically aim to enhance accretionary processes in existing marsh or to create new viable marsh by the manipulation of existing processes (e.g., sediment diversion, crevasse splays).

In addition, the variables to be measured during monitoring have been ranked according to project type and their importance in assessing project goals.

V. GENERAL DISCUSSION

Rationale of Variables

The marsh soil is a result of the cumulative effect of marsh building processes that include the production, transport, and decomposition of organic matter and net influx of inorganic sediments. Depending upon the rate of soil development or marsh accretion, the soil can represent the cumulative impacts of these processes over years or decades. Consequently, monitoring changes in soil variables after project implementation can provide two types of information regarding the success of CWPPRA restoration projects:

(1) documentation of changes in soil composition, stability, structure or development that occur as a direct or indirect result of the project.

Variables:
- Organic matter
- Bulk density
- Water content
- Grain size
- Soil redox
- Soil nutrients
- Soil contaminants (trace metals, synthetic organics, etc.)

(2) documentation of continued development or accretion of the marsh soil that allow for the long-term survival of the marsh in the face of subsidence, sea-level rise, physical erosion, etc.

Variables: Soil vertical accretion
Subsidence
Soil erosion and creation (change in spatial extent)

Relationship to Ongoing Programs

1. The U.S. Soil Conservation Service has produced soil surveys of all coastal Louisiana parishes. These surveys can provide data about specific soil types and their distribution. General information is available concerning such soil variables as percentage of clay, percentage of organic matter, permeability, and moist bulk density. This information can provide a regional context for soil evaluations and may be of value to those responsible for the design and implementation of projects (e.g., levee construction for marsh management projects). The data bases used for soil characterization include specific measurements of soil physical variables and also pH, exchangeable cations, exchangeable aluminum, phosphorous, and particle size, and are available through Wayne Hudnall, Agronomy Department, Louisiana State University, for all Louisiana parishes for which soil surveys have been conducted since 1975.

2. Much of the existing data collection and monitoring efforts that concern soils and sediments are project specific. They include monitoring of individual marsh management plans and scientific research projects designed to either resolve particular management issues or increase understanding of marsh system function. The U.S. Geological Survey is presently participating in two such initiatives. The first involves detailed examination of the physical processes of wetland loss and includes measures of marsh soil bulk density, organic matter content and accretion, as well as field and modeling studies of the movements of freshwater and sediments through marsh areas. The second examines the impact of marsh management on marsh accretion and sedimentation and is being conducted in cooperation with the U.S. Fish and Wildlife Service. The project uses various approaches to the measurement of sediment deposition and marsh accretion and compares experimental marsh management areas, which are being actively managed, with control areas.

   Such studies, and the sampling strategies they develop, can provide data to be used as part of a plan to evaluate the success of CWPPRA projects, especially where they provide information on regional patterns or the character of various marsh types. An example of this use of existing information is in the evaluation of subsidence. The framework geology of an area is particularly important in determining its subsidence potential, and existing studies have identified broad differences in subsidence between the chenier plain and the deltaic plain, as well as more localized variations within hydrologic basins. Because of the purpose for which the data was originally collected, it may not be sufficiently specific to be used in the evaluation of individual projects. Other sources that can indicate subsidence potential (e.g., fault maps) may be available in a more detailed form. Such issues are reflected in the priority that individual variables are assigned in the monitoring matrix (Table 7).

Table 7. Monitoring matrix.

	Class	Accretion	Subsidence	Organic matter	Bulk density	Water content	Grain size	Soil redox	Erosion/ creation large scale (mapping)	Erosion/ creation small scale
Freshwater diversion	B[a]	2, 1a[bc]	2	1	1	1	3	2	3	N/A
Sediment diversion	C	1	1	1	1	1	1	2	1	N/A
Marsh Management	B	1	2	1	1	1	4	1	3	N/A
Dredged material	A	1	2	1	1	1	3	2	N/A	1D, 4M[d]
Barrier island restoration	A	1	3	3	3	3	2	4	N/A	1
Shoreline protection	B	2, 3c	4	3	3	3	3c	4	N/A	1
Vegetative plantings	B	2	4	2	2	2	3	2	N/A	1
Sediment and nutrient trapping	C	1	1 Basin	1	1	1	2	3	N/A	1
Hydrologic restoration	B	1	2	2	2	2	3, 2d	2	3	2 e

[a]A - Create new marsh by artificial means, not manipulate processes.
B - Manipulation of soil processes is a minor aim of project but impact on soil occurs.
C - Project aims to enhance accretionary processes or create new marsh using natural processes.

[b]1 - Primary objective
2 - Secondary objective
3 - Tertiary objective - long term evaluation
4 - Lowest priority - long term evaluation

[c]a - depending on the scale of monitoring for vegetative vigor/growth
b - higher priority of no previous information on soil quality available
c - higher priority if marsh creation is expected
d - if riverine sediment transport paths are affected
e - small scale monitoring required if marsh creation is expected

[d]D - importance at design stage
M - importance for monitoring
Basin - basin scale subsidence information only

3. The cost effectiveness of CWPPRA monitoring versus the use of existing data collection programs depends upon a variety of factors. If certain State or Federal agencies presently have personnel involved in data collection in the coastal zone, it may be appropriate, and cost effective, to incorporate them into a CWPPRA monitoring plan. However, the specific variables and the experimental design for CWPPRA monitoring should be determined independently of these programs in order to provide data that can be used in a statistically valid evaluation of the CWPPRA projects. Where these data collection efforts coincide with ongoing efforts, interagency cooperation is encouraged to increase cost effectiveness. If outside contractors are to be solicited to conduct monitoring efforts, they should be expected to make use of existing efforts and/or logistic support from agencies where appropriate.

VI. METHODOLOGY

Variables

The sediment and soil variables to be included in monitoring plans have been prioritized according to their suitability for evaluating the various types of CWPPRA projects (Table 7). The matrix in Table 7 distinguishes between large-scale and small-scale marsh erosion and creation variables. Large-scale monitoring variables are those that can be undertaken by mapping from aerial imagery, while small-scale monitoring variables are required where changes at a scale of meters are important to the project and must be determined on the ground.

Selection of Sampling Sites

Subsidence is a rapid, highly variable process throughout the Louisiana coastal zone, and all of the proposed CWPPRA projects will be constructed within environments experiencing subsidence. The rate of subsidence can have a dramatic effect on the success of a project. In projects designed to manipulate water and sediments for wetland restoration, the chances of success are greater in areas with lower subsidence rates. It is possible that in some areas subsidence rates are so high that the likelihood of project success is diminished. Because subsidence is an underlying problem for all projects, it is appropriate that it be addressed both at the basin and project specific levels to successfully plan for the management of the coastal zone, and for effective evaluation of project success.

To scientifically evaluate the success of projects, effective comparisons must be made between control and project areas. Certain criteria should be followed in control area selection:

* In projects that impact significant areas of existing vegetated marsh there will probably be gradients in marsh topography, soils and accretion between streamside areas, and back-marsh areas. Where this is the case, sampling sites should be selected consistently in either or both of these zones so that similar environments are being monitored.

* Differences in soil composition and the relative importance of organic and inorganic accretionary processes are also well established between marsh habitat (as defined by salinity and vegetation zones). If the project area includes sizeable areas of more than one marsh habitat comparisons between control and project areas should be made for each marsh habitat. This is necessary to ensure that comparisons are made between like environments.

* Control and project areas should be comparable in their vegetation (within marsh habitat), hydrology, and proximity to sediment sources. The amount of acceptable variability varies according to the number of control areas selected (see Experimental Design section).

* Control and project areas should be comparable in the thickness of the marsh soil. This provides the substrate for marsh growth and is the zone where changes resulting from project implementation will be identified. Previous studies by the U.S. Soil Conservation Service and Louisiana Geological Survey have noted some variations in the depth to the "clay horizon." In order to make effective comparisons between control and project areas, variations in the thickness of marsh soil must be examined before sampling sites are selected.

The validity of the comparisons made between project and control areas will depend upon the number of replicate samples that are taken. The project and control areas should be divided into marsh habitats and at least five replicate sample sites selected randomly within the areas. For instance, if the project area includes both brackish and saline marsh habitats and the study is to consider only back marsh locations, then five brackish-backmarsh-control, five brackish-backmarsh-project, five saline-backmarsh-control, and five saline-backmarsh-project sampling sites should be selected. It is necessary to ensure that control and project areas are comparable. If the project area is large, then sample size should be increased. It is essential that sampling sites are not chosen for logistic reasons but to represent the marsh area being studied. Boardwalks may be necessary to prevent unnecessary disturbance in areas where frequent access is necessary. In all cases, sampling on all areas should be conducted during as short a period as possible to prevent the confounding effects of unpredictable extreme events.

Marsh accretion and soil development are mediated by marsh hydrology and vegetative growth. If monitoring is to be conducted regarding hydrology and vegetation, the understanding of marsh function and the impact of the project will be greatly enhanced by coordination of sampling sites and frequencies. Indeed, the monitoring of marsh-water levels and vegetation productivity (aboveground and belowground), in particular, will enhance the understanding of project impacts gained from the monitoring of marsh accretion and soil development. Consequently, the overall monitoring strategy should allow for coordination between monitoring protocols. Preferably, the same agency or contractor should be responsible for these aspects of the monitoring, or a mechanism for cooperation should be established.

Sampling Design

The sampling matrix (Table 8) shows three strategies for sampling the different types of projects according to the frequency of sampling. The basic monitoring is for Class A projects; more detailed monitoring is proposed for Class B projects; and Class C projects require the most intensive monitoring as soils and sediments are included in the primary objectives of the projects. In addition, for projects where no control sites are available, pre-project monitoring of certain variables is proposed to provide baseline data. These are believed to be the minimum requirements necessary to meet the mandate of CWPPRA for scientific evaluation of project success.

Table 8. Sampling matrix.

	Basic class A	Better class B	Best class C	No control any class
Accretion				
Feldspar markers	A[a]	S	S	
Sediment-erosion table		A	S	
Radionuclide dating			Once only	Once only
Subsidence				
Carbon-14 dating	Once only			
GPS		C		
Extensometers			C	
Organic matter content	A	S	S	Pre-project
Bulk density	A	S	S	Pre-project
Water content	A	S	S	
Grain size	A			Pre-project
Soil redox	A	S	S	Pre-project
Erosion/creation large scale	A			
Erosion/creation small scale	A			
Nutrients	Once only	A		Pre-project
Pollutants	Once only	A		Pre-project

[a] A = Annual
S = Seasonal
C = Continuous

Methods

Soil properties - organic matter content, dry bulk density, water content, grain size

Core samples should be taken from the marsh for the evaluation of these variables.[1] The technique used for coring the marsh is important because inappropriate techniques can cause compaction of marsh sediments and particularly inaccurate measurements of dry bulk density and water content. The best method, which works in all marsh habitats (saline through fresh) and with minimum disturbance to the marsh surface, is cryogenic coring. This involves the freezing of the marsh onto a copper tube and the extraction of a small diameter (5 cm) core without compaction (Knaus and Cahoon 1990). The cores can be sliced into 1 cm or larger segments while still frozen. This method is more field intensive than other methods involving coring devices, but the frozen cores allow easier laboratory analysis for bulk density than other standard practices (e.g., Procedure 4A in U.S. Department of Agriculture, Soil Conservation Service 1984). Alternative coring methods usually involve some compaction of sediments, which can be critical in the evaluation of soil bulk density. A large-diameter (15 cm) core tube can be used to minimize compaction but it usually has to be dug from the substrate causing considerable disturbance. Such disturbance is not appropriate in areas that are being monitored, i.e., where repeated sampling is required. The core segments should be weighed while wet and then oven dried before reweighing. The difference in weights indicates the water content of the soil and the weight of the dried segment which, when standardized for the segment volume, provides the dry bulk density. Organic matter content can be similarly determined by loss to ignition at 375°C for 16 h in a laboratory muffle furnace (or see Procedure 8F in U.S. Department of Agriculture, Soil Conservation Service 1984). Size determination of the ashed sediment samples by using a combination of sieving and pipette/Coulter Analyzer techniques will provide soil grain size data.

Cost per sample[2]:	Organic matter content	$100
	Dry bulk density	$100
	Water content	$50
	Grain size	$100

Accretion (Feldspar)

Feldspar marker horizons should be established at each sampling site. Areas should be at least 50 cm x 50 cm and the layer of feldspar should be at least 3 mm thick. The increment of soil deposited and accumulated above marker horizons should be monitored seasonally. The cryogenic coring technique should be used to sample the surface soil layers at randomly selected locations and the increment of accumulation measured to 0.5 mm. Alternative techniques for sampling feldspar marker horizons,

[1] The depth to which these variables are measured within the soil and the number of samples taken from each core (e.g., 5 cm, 10 cm , 15 cm, etc.) will depend upon the nature of the project, but will be consistent between sampling within the project and control areas.

[2] Costs are very approximate and depend upon who is conducting the sampling and sample processing. Estimates were made based upon one agency or contractor conducting the monitoring and taking samples for all analyses during the same field trips. Project access costs (for example, if an airboat is required) could increase costs. Estimates were based on $100 per day for boat access to project areas. For airboats this would increase to $450.

including the use of thin-walled aluminum-core tubes, which are then frozen and split to reveal the feldspar horizon, are not effective in all wetland types. Highly organic soils, such as those in fresh to intermediate marshes, are very readily compacted by this technique. Cryogenic coring is the optimum, and it provides data in the field rather than requiring additional laboratory work.

Cost per measurement[3]: $250

Accretion (SET)

The sedimentation erosion table (SET) technique was originally used for measuring small changes in elevation on tidal flats in the Netherlands (van Erdt 1985) and is presently being used in marsh surface studies in Louisiana and Georgia. A 7.5-cm diameter aluminum pipe is inserted into the marsh surface using a vibracore until it will penetrate no further and then trimmed to within 30 cm of the marsh surface. The base of this pipe represents a datum against which marsh surface elevation is measured. A smaller notched pipe is cemented into the top of the aluminum pipe and this becomes the base for the sedimentation table. Bases are permanently located at sites where NVA (net vertical accretion) is to be measured. The sedimentation table is placed on the notched pipe during measurement. The distance between the table and the marsh surface is measured by using nine thin aluminum rods. Small discs at the end of the rods prevent penetration of the sediment surface. Changes in the distance between the marsh and the table represent changes in the elevation of the marsh surface. For each base the table can be placed in four positions, coinciding with the points of the compass, to give a total of 36 measures of marsh elevation for each manipulative plot.

Cost of set-up: $450 per site
Cost of measurements: $250

Accretion (radionuclide dating)

^{210}Pb dating of marsh soils can indicate the long-term (> 100 years) accretion rate of the marsh (DeLaune et al. 1989). The procedure involves coring the marsh surface and partitioning the core into vertical segments. The activity of the radionuclides in each segment can be plotted against depth to reveal the vertical profile. The slope of the activity profile is proportional to the rate of marsh accretion (DeLaune et al. 1989). These analyses should be handled by workers with suitable equipment and experience.

Cost of analysis: $1,000

Subsidence - basin scale

Historical tide-gauge trends can be determined by using data from existing long-term gauges operated by the National Ocean Service and the U.S. Army Corps of Engineers. In addition, within each basin, a systematic vibracore survey should be conducted to determine long-term subsidence by using radiocarbon analysis of buried horizons. In addition, GPS benchmarks and extensometers can be used to monitor subsidence. Their location should be based on an understanding of the framework geology of each basin. Vertical extensometers are used to monitor aquifer compaction caused by withdrawal of groundwater. They consist of a well with a casing installed to a chosen depth. A pipe is placed inside the casing and anchored to the bottom of the casing. If the formation above the base of the casing compacts, the pipe appears to

[3] Includes costs for establishing feldspar plots.

rise above the ground because it is free to move. Nests of three extensometers completed at different depths can be used to determine the amount of shallow compaction (or subsidence) and how it is vertically distributed.

Cost per vibracore:	$2,000
Cost per extensometer:	$14,000

Subsidence - project scale

Tide gauges established within each project (by the hydrology group) should be tied into the existing regional network of long-term gauges. Analysis of annual trends in tide-gauge data for long-term stations should be continued, with additional establishment of GPS benchmarks and extensometers (see above) at each project, which are tied to the basin-scale network.

Costs: See above.

Soil redox potential

Soil redox potential should be measured *in situ* at 5-cm intervals below the marsh surface by using brightened platinum electrodes (Mendelssohn and McKee 1988). The depth to which measurements need to be made will depend on the particular project but should be at least 20 cm to coincide with samples taken for chemical analyses.

Cost of profile measurement: $75

Marsh erosion and creation - large scale

The methodologies and costs for this type of monitoring fall under the auspices of the habitat mapping group. Those types of projects that require this evaluation are indicated in Table 1, and we defer to the recommendations of the habitat mapping group regarding the acquisition of these data.

Marsh erosion and creation - small scale

Small-scale changes in the position of the marsh edge can be determined by one of two techniques:

(1) Repeated surveys of marker stakes (standard beach survey technique).
(2) Repeated measures of the position of the marsh margin in relation to a fixed point within the marsh (Letzsch and Frey 1980).

Which technique is most appropriate will depend upon the individual projects, substrate conditions, and the rate of expected erosion and progradation. The survey technique provides information on marsh morphology and is more accurate but requires experienced personnel for surveying. The Letzsch and Frey technique requires the insertion of posts at fixed positions in relation to each other and the original marsh edge. Subsequent measurements are made with a tape measure and do not require experienced personnel. Costs vary accordingly.

Cost of measurement: $150-$300

Soil nutrients and contaminants

The soil and sediments subgroup identified soil nutrients and contaminants as important variables to be monitored. The methodologies and costs for these variables fall under the auspices of the water quality subgroup and will not be addressed in this report.

VII. HISTORICAL DATA

Very little historical data on soils and sediments issues exist in established data bases. The data sources and programs described in the *Relationship to Ongoing Programs* section all provide some degree of historical data. The published scientific literature also contains vast bodies of knowledge concerning soils, subsidence, and marsh accretion in Louisiana. This protocol has been developed in awareness of these previous studies and builds upon that information. A review of this literature was considered beyond the purview of this subgroup.

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I. TITLE: VEGETATIVE HEALTH MONITORING ON CWPPRA PROJECTS IN COASTAL LOUISIANA

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IV. INTRODUCTION

The vegetative health monitoring subgroup of the CWPPRA Monitoring Work Group was tasked to develop vegetative protocols and analyses required to determine the degree of success of the various types of projects built under the CWPPRA. The act specifically asks for the development of projects that significantly contribute to the long-term restoration or protection of the physical, chemical, and biological integrity of coastal vegetated wetlands. The major goal of protection projects is to slow or reverse coastal erosion rates, while the major goals of restoration projects are to preserve, enhance, and/or promote the growth of emergent and submergent vegetation. These goals will be evaluated through the determination of acres of wetlands saved or created. Vegetative health monitoring allows us to determine to what degree the predicted response is occurring other than by the mere presence or absence of vegetative communities.

V. GENERAL DISCUSSION

This section provides information on why certain vegetative health variables were chosen and others were not, what additional issues need to be addressed, and how vegetative health monitoring ties in to other monitoring initiatives.

Rationale

The following variables were chosen because they are proven measures of vegetative health.

Species composition

This variable is a basic structural measure for determining what plant species are present. Plant species have specific tolerances to salinities and water levels, as well as varying levels of wildlife habitat use; therefore, they can be used as an indicator of change.

Relative abundance

This variable goes hand in hand with species composition. Relative abundance more accurately documents the degree of change by providing a measure of dominance and evenness of species. It is not just a measure of percent cover, but also indicates what species dominate the area and whether that species has a high value relative to project objectives (wildlife, cover, bank stabilization, etc.).

Aboveground biomass

This variable provides an indication of the overall vigor and health of the marsh and can be used as a conservative estimate of productivity.

Herbivory

This variable can be an important factor in determining success. Herbivory can be locally intense, very destructive, and costly relative to replanting vegetative projects.

Belowground Biomass and Productivity

It is well established that belowground productivity provides a significant contribution to the overall productivity of ecological systems (Vogt et al. 1986). However, accurate measurements of belowground biomass and productivity are difficult and expensive to obtain (Symbula and Day 1988). These measurements are beyond the realm of this monitoring initiative and would be more appropriately investigated by the scientific community.

Ongoing Programs

Currently, there are no ongoing programs that are providing vegetative health monitoring throughout coastal Louisiana. There are, however, a large number of projects and studies that have collected vegetative health data, and they would be useful in a historical context.

VI. METHODOLOGY

This section defines those variables chosen to monitor vegetative health. A recommended protocol for quantitative sampling of each of the variables is identified, with a discussion of its advantages and disadvantages. In addition, qualitative measures have been identified for use if a quantitative approach is not feasible.

Species Composition

This variable provides an inventory of plant resources by determining what plant species, vegetation types, and communities are present. It requires compiling a list of all species encountered within an area that best represents the community. Although this type of survey indicates what new species occur and existing species disappear with time, it cannot indicate change in vegetational importance unless a measure of abundance or dominance is provided. Therefore, it is recommended that species composition and relative abundance be measured at the same time by using the protocols discussed under relative abundance.

Relative Abundance

Relative abundance provides an estimate of the number of individuals per species in a given sample area. It can be measured by cover estimates or stem counts, depending on whether the measurement needs to be relative or absolute. It is limited by the preciseness of measure, with the potential for introducing bias from one individual to the next. Therefore it is recommended that the same individual(s) conduct the monitoring every sampling trip, if at all possible.

The Braun-Blanquet method (Mueller-Dombois and Ellenberg 1974) should be used to identify species compositions and abundances. It requires compiling a species-area curve, which will determine the minimal sample area size. These samples should fulfill the following requirements: the cumulative plot area should be large enough to contain all species, and the habitat should be as uniform and representative as possible. The Braun-Blanquet Cover-Abundance Scale provides absolute values in relation to fixed plot sizes. Scale values that are chosen should not be deviated from for reasons of comparability.

The advantage of this method is that it is simple, comparable, and accepted by ecological investigators. It is also a semi-quantifiable approach that is less time and labor intensive than stem count methods. The disadvantages include subjectiveness in the cover estimates as well as decreasing accuracies with increasing plot sizes. Additionally, care must be taken in selecting the size, shape, and numbers of plots.

Ocular estimates and low-level aerial photography are qualitative techniques that could be used to measure relative abundances. Another quantitative technique that could be used is stem counts.

Aboveground Biomass

This variable provides a measure of growth, health, and vigor of plants by obtaining the weight of vegetation per unit area. The limitations of this measure include its difficulty in being used in large plots and in woody vegetation.

The clip-plot method (Mueller-Dombois and Ellenberg 1974) should initially be used to obtain aboveground biomass. It would require the clipping of all aboveground matter in established plots, drying it in an oven, and weighing it. Plot size and shape are just as important for obtaining accurate estimates of biomass as they are for the other measures.

The advantages of this method are that it is quantifiable, comparable, and accepted by ecological investigators. The disadvantages include it being a destructive technique and time-intensive. It is recommended that clip-plots be used until a regression line between size and biomass can be developed. This regression could be obtained by counting stems and measuring heights.

Another method that could be used is airborne remote sensors that use Landsat Thematic Mapper and SPOT satellite images to quantify and map the distribution of live aerial biomass in monospecific marshes.

Herbivory

Herbivory is the consumption of all or part of a plant by a consumer. It can be calculated directly by a measurement of the plants themselves or indirectly by measuring the intensity of the herbivores in relation to a unit area. The limitations include the ability to determine cause and effect in terms of survival and stress.

A permanent plot method will be used to evaluate the effects of herbivory. All measurements and techniques described above will be evaluated in caged versus uncaged permanent plots in problem or potential problem areas.

The advantage of this method is that it will provide a structural estimate of potential herbivore impacts without too much additional effort. A disadvantage would be that it would not provide any measure of functional impacts.

It is suggested that during the project development stage, the evidence of herbivory should be evaluated to determine whether a qualitative or quantitative monitoring approach is necessary. For areas with intensive herbivory, a qualitative approach of looking at the presence or absence of vegetation by ocular estimates and/or low-level photography would suffice if historical vegetative composition is known.

General Recommendations

It is recommended that the Braun-Blanquet method be used when applicable because it has the broadest application for quantifying shifts in community composition and abundance. All other measurements can be incorporated into the sampling design required for this method in order to be cost and labor efficient.

Sample designs will be specific for each project. Random selection of permanent transects or plots would be preferred, and distribution and frequency depend on project area and heterogeneity.

The minimum sampling frequency for all variables is annually. Within highly diverse fresh marshes, minimum sampling should occur in the spring and fall because of seasonal species changes, which do not occur extensively in brackish and saline marshes.

The cost estimate for each field visit to the project area is $2,000. Aboveground biomass can be analyzed for $10.00 per sample. These costs will vary depending on size and heterogeneity of the project area and mode of transportation (i.e., airboats).

Resources and project-specific goals will dictate what and how frequently vegetative health variables will be monitored. However, our recommendation is to use resources on habitat mapping first because it provides the baseline for monitoring habitat health.

The broad goals and methods of vegetative monitoring will be more specifically developed on the project level. Each project type may vary somewhat in methodology and frequency of sampling depending on the size and scope of the projects as well as on project-specific objectives.

VII. PROJECT TYPES REQUIRING MONITORING

The monitoring work group has identified nine types of projects for which vegetative health monitoring requirements are to be developed. The types of projects listed in Table 9 have been prioritized regarding their need for vegetative health monitoring. In addition, a determination of whether this monitoring should emphasize qualitative, quantitative, or mixed approaches is identified. Qualitative approaches are used on projects whose response is to create new marsh. These approaches are concerned with identifying the presence or absence of vegetation. Quantitative approaches are used on projects whose response is to shift community types. The emphasis is on determining how much of a difference there is between areas with and without project conditions. These approaches are not only concerned with identifying the presence or absence of vegetation, but also how the vegetation structurally and functionally responds to the projects. Mixed approaches may be used on projects that require some qualitative and some quantitative analyses.

Table 9. The nine types of projects for which vegetative health monitoring requirements are to be developed and their priorities.

Project type	Ranking	Monitoring emphasis
Freshwater diversion (FD)	1	quantitative
Sediment diversion (SD)	3	qualitative
Marsh management (MM)	1	quantitative
Hydrologic restoration (HR)	1	quantitative
Beneficial use of dredge material (DM)	3	qualitative
Shoreline protection (SP)	4	qualitative
Barrier island restoration (BI)	3	qualitative
Vegetative plantings (VP)	2	mixed
Sediment and nutrient trapping (S/NT)	2	mixed

The specific monitoring variables and their ranking for each project type are listed in Table 10. Rankings of 1 or 2 indicate the importance of these variables in determining if the primary and secondary objectives of a project are being met.

The vegetative health subgroup also identified water level, salinity, temperature, pH, dissolved oxygen, turbidity, and macronutrients (N, P, K) as important variables relative to vegetative health monitoring. The methodologies and costs for these variables fall under the auspices of the hydrology and water quality subgroups and will not be addressed in this report.

Table 10. Monitoring matrix for vegetative health projects.[a]

Project type	Species composition	Relative abundance	Aboveground biomass	Herbivory
FD	2	1	2	4
SD	2	2	3	3
MM	2	1	2	4
HR	2	1	2	4
DM	2	2	3	3
SP	4	3	4	4
BI	2	2	3	3
VP	2	1	1	2
S/NT	2	2	3	3

[a]Key: 1) primary objective
2) secondary objective
3) tertiary objective - long term evaluation
4) lowest priority - long term evaluation

Note: Species composition is a qualitative measure.
Relative abundance is a quantitative measure.

VIII. HISTORICAL DATA

Vegetative surveys have been conducted in coastal Louisiana every 10 years since 1968 by the Louisiana Department of Wildlife and Fisheries and Louisiana State University. Descriptive analyses have been compiled on vegetation, water, and soil characteristics; however, these variables have not been correlated (Chabreck 1972). Vegetative type maps have been completed for the years 1968, 1978, and 1988. These maps illustrate fresh, intermediate, brackish, and saline marsh areas as well as nonmarsh areas. The associated data base can provide historical information and may be used as a baseline for some projects.

The Coastal Restoration Division of the Louisiana Department of Natural Resources is in the second year of cooperative agreements with the State Soil and Water Conservation Committee and the Coastal Soil and Water Conservation Districts to implement over 50 vegetative restoration projects. Monitoring of these projects includes percent survival, number of new shoots, lateral spread, height, basal cover, vigor, seed head formation, insect damage, and herbivore damage. The herbivore monitoring in particular can provide some useful information.

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I. TITLE: HABITAT MAPPING OF RESTORATION AREAS

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IV. INTRODUCTION

Selected wetland areas throughout coastal Louisiana have been designated by the CWPPRA as potential restoration projects. Habitat mapping can provide a useful tool in the monitoring of restoration projects. The previous wetland mapping was based on aerial photography acquired at a scale of 1:63,500 and mapped at a scale of 1:24,000. The resulting maps have not proven feasible for marsh restoration and management use.

The U.S. Fish and Wildlife Service (USFWS), National Wetlands Research Center (NWRC) is presently producing 330 wetland and upland habitat maps for coastal Louisiana using 1988, 1:63,500 scale color infrared photography. Two hundred and twenty-three of these maps will be comparable to the previous mapping efforts of 1956 and 1978. In fact, many of the completed maps and the digital data available from them are being used in the planning process for the CWPPRA. Although this habitat mapping is providing data for basin-wide planning such as measuring wetland change, land loss, and marsh loss, the detail is insufficient for providing similar comparisons for each restoration project type. The regional mapping projects of NWRC and U.S. Army Corps of Engineers (USACE) are based upon 1:63,500 scale aerial photography or base maps; this scale precludes the ability to photointerpret and map consistently or economically those parcels of marsh or open water that are less than one acre in size. Consequently, studying the processes or documenting the change in the habitats in restoration project areas is difficult.

The objectives of habitat mapping are:

* To provide a data base from which basin-wide wetland trends can be measured and to update the 1988 data base with 1993 thematic mapper data

* To provide baseline maps for a historical time period for the vegetation within each of the restoration sites prior to the restoration project being implemented

* To acquire aerial photography for each restoration site for successive years and provide that photography to other monitoring subgroups

* To develop large-scale, detailed habitat maps (and assess the classification accuracy of these maps) for successive years that can be used by the other monitoring subgroups

* To coordinate with the vegetative health subgroup in fieldwork, data collected, and maps generated

* To assess the impacts or changes brought on by the restoration activity

* To develop digital data for selected restoration projects on an as needed basis.

V. GENERAL DISCUSSION

Data Availability

Wetland and upland habitat maps and digital data are available from USFWS for the whole Louisiana coastal zone for 1956, 1978, and 1988 at a scale of 1:24,000.

The Louisiana Department of Natural Resources (LDNR) Coastal Management Division has classified satellite thematic mapper (TM) data for the whole coastal zone for winter 1984-85. Geocoded (Louisiana State Plane-South Zone) TM data are available for winter 1990-91 for the whole coastal zone. Partial January 1988 geocoded TM data are also available for the eastern half of the coastal zone.

Unclassified advanced very high resolution radiometer (AVHRR) digital data are available through the Louisiana State University on a daily basis at a course resolution of 1 km.

Land and water change data and maps are available from the USACE for the Mississippi Deltaic Plain for the 1930's, 1950's, 1970's, 1980's, and 1990's at a scale of 1:62,500.

Digital line graph (DLG) data are available from the USFWS for transportation, hydrology, and public land survey for all 1:100,000 scale maps.

Digitized 1:24,000 data for portions of the coastal zone (non-U.S. Geological Survey [USGS] source) are available from LDNR in DXF format. LDNR is in the process of entering a contract with the USGS to complete all 1:24,000 DLG's south of 30 degrees latitude within Louisiana. Expected completion date is early 1994.

Transportation and boundary digital data are available from the Louisiana Department of Transportation for the whole coastal zone.

Scale

1) Basin-wide

Minimum mapping scale should be 1:100,000.

Use the existing USACE, USFWS, and LDNR digital data available.

Acquire and classify five geocoded scenes (180 x 180 km/scene) in the fall and winter 1993-94 to cover coastal Louisiana and update the 1988 habitat data base. The comparison of the USFWS habitat data to classified TM data has several inherent problems that will affect the resultant acreages of habitat change.

2) Project specific

Minimum mapping scale should be 1:24,000 with the following recommendations for each project area:

Acreage	Scale	Minimum Mapping Unit
Under 200 acres	1:6,000	0.05 acre
200 acres to 20,000 acres	1:12,000	0.1 acre
Over 20,000 acres	1:24,000	1 acre

Color infrared aerial photography must be collected as the primary mapping medium.

The period from September to early December is the optimum window for obtaining the aerial photography.

High water conditions should be avoided by acquiring the photography during normal to low water conditions (flat tides).

The aerial photography should be collected by basin to avoid the changing water and vegetation conditions that can often vary from one basin to another.

The aerial photography should be collected each year for the first 3 years then every third year thereafter. However, this should be considered on a case by case basis after the first year because some of the projects may have changes that necessitate the acquisition of aerial photography more or less frequently than every third year.

3) Historical

Use the existing USFWS aerial photography from 1978 and enlarge to 1:24,000 scale, photointerpret the habitats, and map each unit to provide baseline data to measure changes against. For areas that are to be mapped at 1:24,000 scale, the 1988 USFWS habitat maps can be used as an additional time period since those data are readily available. For areas to be mapped at the 1:12,000 scale, the 1978 photography will be enlarged to 1:12,000 scale and photointerpreted. For areas to be mapped from present and future photography at 1:6,000, the 1978 photography cannot be enlarged to 1:6,000 and maintain sufficient clarity and resolution. Therefore these areas will be mapped at 1:12,000 for 1978.

Classification

The basic goal of the habitat mapping program is to provide a consistency of products through the use of the USFWS wetland classification system (Cowardin et al. 1979) and upland habitat delineation (as modified by Anderson et al. 1976).

1) Basin level

The 1993-94 TM imagery should be classified to Level I (modified by Perwitt Braud after Anderson et al. 1976) consisting of approximately 14 land cover categories following LDNR procedures used for the 1984-85 imagery.

2) Project specific

Use the Cowardin et al. (1979) classification to the subclass level. As per the wishes of other monitoring subgroups, water regime, salinity, and species modifiers may be added to the mapping classification if sufficient fieldwork is funded and/or data from other monitoring subgroups are available. Additional modifiers, e.g., for flotant and managed areas may be added.

3) Historical

Use the Cowardin et al. (1979) classification for the historical mapping to the subclass level, with the use of water regime and special modifiers.

Fieldwork

Amount of fieldwork depends upon the specific level of the classification desired; the greater the level of classification the more fieldwork and time will be required.

The fieldwork performed in the mapping of projects will be separate from the field data collected by or for other monitoring subgroups. If the mapping field data are deemed usable by other monitoring subgroups, it will be made available to them.

1) Basin level

   Determining basin level habitat acreage depends on the availability of existing ancillary data sets. Complete coverage of the entire Louisiana coastal zone is not available for all years. Some groundtruthing may be necessary to correctly classify newly acquired TM imagery.

2) The fieldwork criteria necessary for the project-specific mapping include

   * location by longitude and latitude and a vicinity requires the use of a global positioning system for location of the following vegetative characteristics:

     predominant species in cover
     other species present
     canopy height
     vegetative vigor
     percent cover

   * water level at time of fieldwork
   * annual fluctuations of water level
   * schedule for groundtruthing
     prior to photointerpretation--all sites
     after photointerpretation--all sites
     review of draft maps--only areas over 20,000 acres
   * salinity from actual measurements managed (if the area is impounded, water level managed, ditched, etc.)

3) Horizontal control (mapping accuracy)

   In the mapping at detailed scales of 1:12,000 and 1:6,000, the placement of targets prior to each aerial photographic flight is necessary to provide control markers that will be seen on the aerial photography. Global positioning systems (GPS) should be used to locate targets and compare positions with the GPS readings recorded during acquisition of the aerial photography.

   Required especially for areas that do not have adequate natural and cultural features to maintain horizontal control for registering aerial photography to base maps.

Products

* Aerial photographs
* Final habitat maps
* Digital data for selected restoration sites
* Field notes
* Classified TM data (including digital and hard copy products) for basin level mapping
* Regional trend maps from basin-level mapping

Dissemination

The products should be made available to researchers and monitoring groups, State and Federal agencies, parishes, and universities; however, all products should be made available to everyone. Reproduction of maps should be made simple. Photograph reproduction will be a problem of photography, maps, and digital data. One agency should be responsible for archiving and distribution of photography, maps, and digital data, but this will be costly.

Review

1) Basin level

   Series of demonstrations for task force and subgroup chairs

2) Project specific

   Internal review

   Regional review

   Draft map review - maps would be available to the public for comments from those interested in reviewing the maps. Schedule, though, may negate this if rushed for time.

Statistical Review

While there are no statistical criteria or standards for mapping, classification and positional accuracy will be assessed in order to estimate the overall accuracy of the data.

VI. METHODOLOGY

Basin-level Mapping

The wetland cover and trend work currently being completed for the CWPPRA task force is establishing historical regional trends on either a basin or coastwide basis. There is no need to repeat this process except to update the coastal trend data sets by including the 1988 habitat data set when completed.

Basin-level mapping for a more recent vintage should use coastwide, level-one classification of geocoded TM imagery. Hybrid image classification techniques should be used to classify the geocoded TM data for major habitat categories. Resulting landcover and wetland trend maps, digital data, and reporting data (acreage by habitat category) generated by GIS analysis of the classified TM data should be made available for each basin in reproducible form.

Project-Specific Mapping

The color infrared aerial photography should be acquired at scales of 1:12,000 or 1:24,000 for each of the restoration projects. Acquisition should be accomplished through a contract with an aerial photographic that uses a 9 inch by 9 inch format camera to provide stereo coverage of each restoration site. The contractor should simultaneously acquire vertical airborne video tape for each site. The photography and video tape should be acquired within a late September to December window for each year from 1992 to 1994, and every third year thereafter. The aerial photography should be acquired for all projects within a basin for each flight. Each flight should avoid high water or high tide conditions.

The aerial photography should be interpreted for wetlands according to the Cowardin et al. (1979) classification system. Uplands within each project should be classified according to the Anderson et al. (1976) upland classification system as modified by L.R. Handley. The photointerpretation process involves the stereoscopic identification of various wetland and upland signatures. These signatures should be delineated by using a 6 x 0-size technical drafting pen and labeled according to the applicable classification system and mapping conventions. Where necessary, the classification system should be modified to fit the needs of these specific restoration projects. For example, because of the large scale of photography being interpreted (1:12,000) for some of the projects, the minimum mapping unit should be decreased to 0.1 acre. The modified mapping unit may also describe additional factors (e.g., salinity, species, density of coverage) if the information is available from the other monitoring subgroups.

Once the photointerpretation process has been completed, the interpreted photographs should be groundtruthed and any corrections should be made. The photographs should then be reviewed for quality control. Here the delineations and interpretations should be checked for positional and thematic accuracy and consistency. The delineations should then be transferred to an overlay placed on a 1:12,000 or 1:24,000 topographic base map. The 1:12,000 scale base maps should be prepared by either photographically enlarging a quarter of a USGS topographic base map or by manipulating the digital data for USGS topographic maps that may be available for some of the quadrangles to the desired scale. Each new 1:12,000 base map will then represent 1/4 of a 1:24,000 USGS topographic quadrangle. The delineations made on the 1:12,000 scale or 1:24,000 scale photography should then be transferred to the base maps by using a zoom transfer scope. The drafted map should be taken to the field for review, and copies distributed for review and comment. Final map production would come after all review comments were incorporated. A large-scale review should follow. In this step the final quality control is performed. All interpretation and mapping should follow the reporting and documentation process developed by NWI.

Deliverables of the mapping project should be paper copies of the maps drafted at 1:6,000, 1:12,000, and 1:24,000 scales. The aerial photography should be available for viewing and for copying on a cost reimbursable basis.

Final habitat maps should be digitized for selected restoration projects. It may not be feasible to digitize each project for each year. The restoration projects to be digitized should be determined on reviewing the draft maps to evaluate the extent of change that has taken place. Digitization should be done using the Analytical Mapping System (AMS) on a UNIX workstation. The AMS digital data should be available in DLG-3 format for use on ArcInfo, Integraph, Infocad, etc. Deliverables will be the digital data on standard tape format and acreage summaries for each quad.

GIS should be used to analyze the digitized habitat maps for the purpose of developing wetland trend maps to identify areas of wetland loss and gain occurring within restoration plans over time. Digital data, wetland trend maps, and reporting data (landcover and wetland trend acreage tables) should be available for use on a cost reimbursable basis.

VII. PROJECT TYPES

Project Ranking

Because the mapping program is providing a supporting role, projects are not ranked by the habitat mapping subgroup but should follow the consensus ranking of the other subgroups to do the project-specific mapping.

Proposed Mapping Scale for Each Project Type

Project	Acreage	Scale
Fourchon	2,300 acres	1:12,000
Gulf Intracoastal waterway to Clovelly wetland	60,000 acres	1:24,000
Cameron-Creole watershed	64,000 acres	1:24,000
Bayou Sauvage National Wildlife Refuge	6,000 acres	1:12,000
Turtle Cove shoreline	1,000 acres	1:12,000
Sabine National Wildlife Refuge	13,000 acres	1:12,000
Vegetative plantings		
West Hackberry	> 100 acres	1:6,000
Dewitt-Rollover Gulf	< 100 acres	1:6,000
Falgout Canal shoreline	> 100 acres	1:6,000
Timbalier Island	> 100 acres	1:6,000
West Bay sediment diversion	9,800 acres	1:12,000
Barataria Bay waterway	1,000 acres	1:12,000
Lower Bayou LaCache	4,200 acres	1:12,000
LaBranche wetlands	300 acres	1:12,000
Cameron Prairie	640 acres	1:12,000
Vermilion River cutoff	200 acres	1:12,000
Eastern Isles Dernieres	100 acres	1:6,000
GIWW to U.S. 90	40,000 acres	1:24,000
Tiger Pass marsh	415 acres	1:12,000
Falgout Canal South wetland	220 acres	1:6,000
Lake Salvador shoreline	>100 acres	1:6,000

1) Projects added in future years should be mapped at scales according to the following guidelines:

Average	Scale
Under 200 acres	1:6,000
200 acres to 20,000 acres	1:12,000
Over 20,000 acres	1:24,000

2) Although the general procedure proposed is to obtain aerial photography for each project for each of the first 3 years and then every third year thereafter, it is the general consensus of the mapping subgroup that this be considered on a case-by-case basis because projects may show significant changes that should be monitored frequently.

Estimated Project Cost	1993	1994	1995
Project-Specific Mapping			
Photointerpreter(s)	$39,000	$79,000	$82,000
Cartographic technician(s)	$55,000	$58,000	$61,000
Geographer	$20,000	$20,000	$20,000
	$114,000	$157,000	$163,000
Photography	$24,000	$30,000	$35,000
Historical photography	$9,000	$4,000	$0
Supplies	$18,000	$12,000	$10,000
Materials (horizontal control)	$8,000	$4,000	$4,000
Travel	$2,000	$4,000	$4,000
Equipment	$106,000	$7,000	$0
	$167,000	$61,000	$53,000
Total cost	$281,000	$218,000	$216,000
Basin-level mapping			
TM scenes	$16,000	$20,000	$0
Geographer (classification)	$10,000	$36,000	$36,000
Total cost	$26,000	$56,000	$36,000
Digitizing selected project-specific maps	$18,000	$38,000	$38,000
GIS analysis of digital data from project-specific maps	$16,000	$36,000	$38,000

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I. TITLE: WILDLIFE MONITORING ON COASTAL WETLANDS PLANNING, PROTECTION, AND RESTORATION ACT PROJECTS IN COASTAL LOUISIANA

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IV. INTRODUCTION

The wildlife monitoring subgroup of the CWPPRA Monitoring Work Group examined the feasibility of developing wildlife monitoring protocols and analyses to determine the success of a wide range of wetland restoration projects planned for coastal Louisiana. The CWPPRA defines a restoration project as a technically feasible activity to create, restore, protect, or enhance coastal wetlands.

V. GENERAL DISCUSSION

The wildlife monitoring subgroup supports a monitoring program to evaluate the success of prescribed restoration projects in maintaining long-term wetland protection and conservation. The subgroup stressed the importance of selecting monitoring variables that are expected to show a direct (cause and effect) response to project design and actions. The subgroup determined that, since wildlife populations are influenced and controlled not only by local or basin-wide wetland conditions, but also by external factors, monitoring wildlife would be neither biologically sound nor cost-effective in evaluating project success. Several subgroup members pointed out that wildlife populations fluctuate greatly over time and space, and establishing statistically valid relationships between project features, wetland responses, and wildlife populations would be very difficult. For these reasons the wildlife monitoring subgroup recommends not developing a detailed, project-specific wildlife monitoring program.

The wildlife monitoring subgroup recognized that populations of herbivorous species such as the nutria (*Myocastor coypus*) and muskrat (*Ondatra zibethicus*) may have a significant effect on the rate of recovery of coastal wetland plant communities. The subgroup felt, however, the herbivory issue could best be addressed by the vegetative health monitoring subgroup.

The wildlife monitoring subgroup identified wildlife surveys conducted by the Louisiana Department of Wildlife and Fisheries (LDWF) and the U.S. Fish and Wildlife Service (USFWS) as having limited value for use in evaluating the success of specific coastal wetland creation and restoration projects. Both agencies collect annual records of waterfowl abundance and distribution within the Louisiana coastal zone, and the LDWF conducts inventories of fishery abundance and American alligator (*Alligator mississippiensis*) populations. The LDWF also periodically surveys colonial waterbird populations in Louisiana's coastal zone. The subgroup felt that some of these wildlife data bases, especially that for the alligator, may provide a valuable general index of the status and trends of wildlife populations across the Louisiana coast where wetland creation and restoration projects are underway. These data sets are, however, not considered to be adequate for use in evaluating the success of specific projects in achieving long-term wetland conservation.

VI. METHODOLOGY

The wildlife monitoring subgroup recommends that current and ongoing LDWF and USFWS surveys be used, where needed, as secondary data sets for examining correlations between wetland changes, wildlife abundance, and distribution problems. When used in conjunction with more quantitative monitoring data for water quality, vegetation, etc., these wildlife data bases may have value in confirming over a broad scale (i.e., entire Louisiana coast) what basin-specific monitoring data show for more localized areas.

Methodologies used by the LDWF and by the USFWS for wildlife surveys are either transect-based or are based on observations made on known wildlife concentration areas.

I. TITLE: ASSESSMENT OF CWPPRA PROJECT IMPACTS ON FISHERY RESOURCES

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IV. INTRODUCTION

Most coastal habitats being lost in Louisiana are valuable in sustaining fishery productivity. Inherent in the goals of the CWPPRA is the idea that projects will be beneficial to coastal fisheries. However, this objective must be considered within the context of the entire program; some projects may benefit fisheries at the expense of other natural resources, and some benefits to fishery resources may not be realized for many years. Determining whether CWPPRA projects have benefited fishery resources will require assessments of impacts after these projects are initiated. The objective of this monitoring plan, therefore, is to provide scientifically defensible data for determining whether CWPPRA projects have had major impacts (either positive or negative) on fishery resources in coastal Louisiana.

All CWPPRA projects have the potential for impacts on fishery resources. Decisions as to the types of projects that should be monitored, however, should be based on the likelihood of these impacts, the time frame of expected impacts, and the difficulty in assessment of impacts.

V. GENERAL DISCUSSION

Variables to be Measured

Ideally, impacts of CWPPRA projects should be assessed by measuring fishery production from a project area. Realistically, however, the effort required to measure productivity is prohibitive, and measures of standing stock must be used as an indicator of fishery value in an area. Each project is likely to have a different assemblage of ecologically important species. These will include the following species of commercial, recreational, and food-chain importance: white shrimp, brown shrimp, grass shrimp, blue crab, stone crab, spotted seatrout, southern flounder, gulf menhaden, spot, Atlantic croaker, red drum, oysters, striped mullet, bay anchovy, and black drum. Other resident forage species may also be abundant, and certain freshwater species may be important in some projects. Most of these species can be sampled with similar gears and sampling designs. Because oysters are sedentary, however, different sampling techniques will be required for this species; monitoring for oysters can also include measures of recruitment, growth, and survival.

Juveniles and small adults (generally less than 100-mm total length [TL]) of the fishes and crustaceans should be targeted for sampling. Because the habitats being modified are usually nursery grounds for the young, juvenile stages are more abundant, making population sizes easier to estimate. Moreover, the best methods have been developed to quantitatively sample these small animals. Large juveniles and adults of these target species, if they are present in the area, will be extremely difficult to sample quantitatively. In addition, abundance measures for older juveniles and adults are subject to greater variances and may not reflect habitat value if populations are reduced by local fishing pressure.

The primary variables to be measured for juvenile fishes and crustaceans should be density (number of animals per area of bottom), size, and biomass. The number of species (species richness) collected within some standardized area should also be recorded. In certain instances, catch in standard gear (such as trawls and seines) may be measured rather than animal density. Catch per standard unit of effort can be useful in assessing relative abundance and species composition, but these data must be interpreted with caution because of the instability in catch efficiency (see Gear Selection).

Important Fishery Habitats

Different coastal habitats support different numbers and species of fishery organisms, and sampling efforts should be stratified within a project area by habitat. Examples of habitats include unvegetated sand or mud bottom, submerged aquatic vegetation, emergent vegetation, organic detrital bottom (coffee grounds), oyster reefs, and channels.

An assessment of relative area for each of these habitats will be necessary to determine sampling strata. Shallow unvegetated bottom is expected to be most common and must be sampled. Submerged aquatic vegetation and emergent shoreline vegetation are known to support high densities of juvenile fishery species and will also need to be sampled if present. Emergent vegetation may be omitted from the sampling program only if sampling can be conducted at low water levels (see section on water level). Sampling crustaceans will probably not be practical on bottoms with large amounts of organic detrital matter (coffee grounds) or on oyster reefs because quantitative sampling of these habitats is prohibitively labor and cost intensive. Combining solid-walled throw traps with the use of rotenone, however, could allow sampling of fishes in these habitats. Although deepwater channel habitats may be important for some animals, most juvenile fishery species are likely to be more abundant in shallow-water habitats. Shallow channels such as marsh creeks may be important habitats to sample.

In some situations, sampling of zones within habitats may be appropriate. For example, high-elevation intertidal wetlands have been shown to support different animal densities and species than low-elevation wetlands. Also, open-water habitats near access structures probably differ from areas further from these structures.

Gear Selection

Gear catch efficiency is a major problem that must be addressed in the selection of sampling gear for CWPPRA projects. Commonly used gear such as trawls and seines, which use the area-sweep method to estimate animal densities, usually have low catch efficiencies. If these efficiencies were stable, appropriate corrections could be made to estimate animal density. Unfortunately, these efficiencies also appear to be highly variable. For example, otter trawls are generally recognized as being selective in the sizes and species of animals caught. This gear catches some unknown percentage (the gear catch efficiency) of the animals present in any given area swept. Catch efficiency varies with net mesh size and with the species and size of the target animals. For small brown shrimp, catch efficiencies of 17.5-52.9% (Loesch 1976), 17% (Zimmerman et al. 1986), and 49% (Minello et al. 1991) have been measured. Catch efficiencies for spot (6%), Atlantic croaker (26%), and anchovies (7%) have also been reported (Loesch 1976; Minello et al. 1991).

A related and more insidious problem is that catch efficiency probably varies with habitat and environmental characteristics, and often these characteristics are related to the treatments being measured in a sampling design. Unless this bias is corrected, site differences attributed to a project may simply be a reflection of a systematic shift in gear efficiency. It has been shown that differences in turbidity affect the catch efficiency of trawls for small fish (Nielson 1983). Vegetation, unconsolidated bottom (coffee grounds), uneven bottom topography, sediment texture, and even temperature are also likely to affect this catch efficiency. Juvenile shrimp often avoid capture in nets because they are burrowed into the substrate, thus all the environmental factors that affect shrimp burrowing (incident light, turbidity, substrate type, predators, hunger level) are candidates for affecting catch efficiency of shrimp. Thus, to make legitimate comparisons among sampling sites and habitats by using catch from sampling gear with low catch efficiencies, researchers must adjust abundance estimates to correct for site-related differences in gear catch efficiency. These corrections could be made for each sampling site and habitat combination by making limited comparisons with gear known to have a high catch efficiency in that habitat.

The confounding problem of variables affecting both animal density and gear efficiency can be avoided if the catch efficiency of the sampling gear is very high. Enclosure devices, such as throw traps or drop samplers (Kushlan 1981; Zimmerman et al. 1984), appear to have high catch efficiencies that do not vary substantially in the presence of vegetation (Zimmerman et al. 1986). In addition, recovery efficiency (a major component of catch efficiency) can be easily measured for these samplers through simple tagging procedures after the sampler has been deployed. The area sampled with throw traps is generally smaller than the area sampled with other types of gear such as seines and trawls, but increasing the sample number can generally compensate for this limitation. Drop enclosures are also limited to water depths less than 4-6 ft, but water depth will probably be shallow for most habitats to be sampled in CWPPRA projects.

In some limited situations, trawls and seines may be useful in monitoring fishery abundance at CWPPRA project areas. These gear can be deployed in deeper water, sample larger areas, and provide data that is more comparable with historical data bases. Trawls and seines also have the advantage of being relatively easy to use, and they are more familiar to people conducting monitoring; they are often preferred by state research agencies. In general use, however, these gear are often only appropriate for measuring the presence or absence of species in an area. Abundances cannot be accurately measured in habitats where emergent or submerged vegetation is present; thus comparisons among habitats are not possible. Trawls and seines can provide semi-quantitative (moderately stable catch efficiency) abundance samples of non-burrowing animals in nonvegetated habitats. These data can be useful in making comparisons among nonvegetated areas if environmental factors that affect catch efficiency (such as turbidity and bottom type) are examined as potential causes of bias.

Monitoring Costs

The fishery monitoring subgroup has attempted to address the problem of limited monitoring funds in several ways:

1) By restricting the types of projects that require fishery monitoring.

2) By emphasizing monitoring mainly of juvenile fishes and crustacea that occur in greater numbers and are more readily sampled.

3) By limiting assessment of impacts to more easily measured variables such as standing crop, size, and species richness rather than attempting to measure productivity. Productivity estimates (growth, survival, recruitment) are only recommended for oysters.

4) By limiting the recommended temporal replication of sampling efforts.

The following prioritized list (one being most important) of sampling procedures should be used to reduce sampling effort and cost:

1. Collect high quality samples to accurately measure animal density.
2. Select appropriate controls.
3. Collect sufficient sample numbers at any one time for rigorous hypothesis testing.
4. Sample all dominant habitats.
5. Collect samples during biologically different times of year (early spring, late spring, fall).
6. Collect samples in successive years following project implementation.
7. Collect samples every 2 months during a year.

Procedures 1-3 in this list are mandatory, and procedures 1-5 are probably necessary to provide a scientifically sound assessment of project impacts.

The projected cost of assessing impacts on fishery resources depends upon the size of the project areas, the number of important fishery habitats present, and the variability of the measured variables (this determines sample size). Following the procedures outlined in this document, a cost of approximately $150-$200 per throw-trap sample might be expected.

The Water Level Problem

The effect of water-level fluctuations must be considered in estimating the abundance of fishery organisms (see Figure 2). Most fishery species require water and are associated with the bottom in some manner. Changing of water levels at a site, either from tidal fluctuations, water-level control structures, or alterations in freshwater inflow can drastically alter density estimates of animals. As an example, the rising tide in many coastal areas can easily cause a two-fold difference in the amount of bottom area flooded in a basin. This doubles the area of bottom available for animals, and if the animals are distributed evenly over the bottom, this tidal flooding will reduce the density of animals by half. If water level is not considered in comparing density estimates among sites or over time, spatial and temporal differences in animal abundance will be indistinguishable from density changes caused by this water-level effect. This concentrating factor at low water levels is often ignored in sampling designs. To further complicate this situation, many animals such as brown shrimp, blue crab, and spotted seatrout are attracted to shoreline emergent vegetation when it is available at high water levels (Zimmerman and Minello 1984). If sampling efforts are concentrated in the adjacent open-water habitats, density estimates for these organisms will increase dramatically as water levels drop and animals are forced out of the shoreline vegetation.

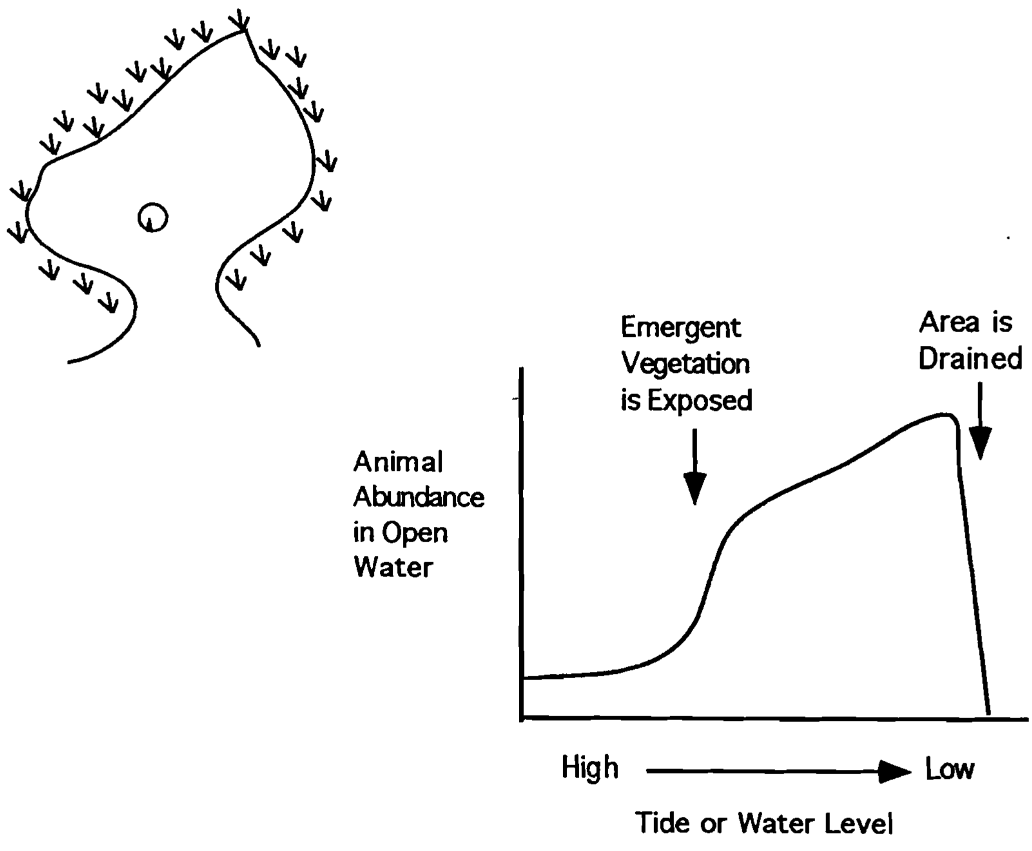

Figure 2. Hypothetical relationship between water level and abundance estimates in a marsh pond.

The most realistic picture of habitat use at a site would require sampling at all water levels in proportion to the time these water levels occur in the sampling area. This approach, however, would increase sample variances and result in unrealistic effort required to detect project impacts. The practical solution to this sampling problem is to sample both the control and project areas at similar water levels. Low-water sampling may be most desirable because it can eliminate the need to sample shoreline habitats (flooded vegetation) and will result in higher open-water densities. However, many locations are inaccessible at low tide except with air boats. In situations where water levels are being controlled as part of the project, sampling study and control areas at similar water levels should still be possible by carefully selecting sampling periods. If water level differences between project and control areas are persistent, all flooded habitats must be sampled, and differences in water levels and area flooded must be considered in interpreting the data.

Common Data

Availability of comprehensive water-quality data (temperature, salinity, dissolved oxygen, turbidity, water level) at the project and control areas will be essential in interpreting sampling results. These variables should also be measured every time a fishery sample is collected. In addition, estimates of coverage for different fishery habitats within project and control areas will be essential for fishery monitoring.

Ongoing Programs

The Marine Fisheries Division of the Louisiana Department of Wildlife and Fisheries monitors fishery species using a variety of equipment at stations in six coastal study areas of Louisiana. Samples are collected with plankton nets, 16-ft trawls, 6-ft trawls, seines, gill nets, and trammel nets. Oysters are sampled with Butler plates, a square-meter frame, and with an oyster dredge. The frequency of sampling and sampling locations are identified in a draft manual of their field procedures on file with the monitoring work group.

VI. METHODOLOGY

Sampling

Density of abundant juvenile and small adult fishes and crustaceans

1) Juveniles and small adults (generally less than 100-mm TL) should be targeted, and the density of animals per square meter of bottom area should be measured. In conjunction with this variable, the size of the organisms, the biomass of dominant species, and the number of species (species richness) collected within some standardized area should also be measured.

2) Throw traps similar to those described by Kushlan (1981) are recommended as sampling gear. The advantages are high catch efficiency in most shallow-water habitats; area sampled is fixed and known; easy and inexpensive to construct; easily deployed from an air boat; and recovery efficiency is measurable. The disadvantages are the area sampled is small, and large and highly motile organisms may avoid the sampler, especially in very clear water. A rough cost estimate that includes all overhead, personnel, and equipment costs would be approximately $150-$200 per sample.

3) Measuring density over time - density should optimally be measured every 2 months following project implementation. Minimally, samples should be collected in early spring, late spring, and fall.

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4) Measuring density over space - spatial coverage and number of samples should be determined by the number of sampling zones identified and the variance among samples.

5) Other prioritized protocol (gear and procedures)

   a) Use of small-meshed seine to completely encircle a known area of shoreline habitat. This technique would have the advantage of sampling a larger area, thus reducing between-sample variability and providing a better estimate of abundance for low-density organisms. The technique could be used in deeper water and on all types of nonvegetated bottom, and recovery of enclosed animals could be measured with simple marking techniques. This seining technique, however, will not work well in vegetation, and sampling is restricted to areas where a suitable bank is present to "haul up" the catch and there are few obstructions (such as oysters, rocks, tires, etc.). Additional disadvantages include the possible enclosure of heterogenous bottom and the severe under-sampling of burrowed and bottom-hiding organisms. The cost per sample for this technique will be substantially higher than for throw traps, but the number of samples required for statistically valid comparisons will be significantly lower. Thus, overall project costs between these two gear types might be similar. The major reason this technique is not generally recommended is that sampling would have to be restricted to only certain nonvegetated habitats.

   b) Use of a beam-trawl. This gear is often used to collect small shrimp and fishes and has a relatively high catch efficiency for shrimp on nonvegetated bottom (Zimmerman et al. 1986). As with a seine, the beam trawl can be used in deeper water and samples can cover larger areas of bottom, thus reducing between-sample variability. This gear, however, is not restricted by access to the shoreline; samples can therefore be randomly distributed within an area. Disadvantages include restriction to sampling on nonvegetated bottom, and even here variability in catch efficiency may be related to environmental factors. The cost of a beam-trawl sample will probably be similar to a throw-trap sample, but the number of samples required in the sampling program will probably be reduced.

Oyster growth and survival

1) A standard set of small oysters will be used to measure growth and survival.

2) Nestier trays containing 20-25 oysters will be placed at selected sites within the study and control areas for the measurement of growth and survival. The advantage of this technique is that the initial size and number of oysters is known, commercial harvesting will not affect measurements, and permission to sample private leases is not required. Disadvantages include problems with vandalism of trays, and measurements of survival and growth in these trays may not exactly reflect survival and growth on reefs. Nestier trays are available for a negligible cost from biological supply houses. The trays are easy to deploy and retrieve, and two people could deploy or "read" dozens of trays in one day. Thus, the major expense will be salaries of personnel.

3) Measurements over time - trays will be monitored quarterly for oyster growth and survival. Trays and oysters will be replaced annually in January.

4) Measurements over space - spatial coverage and number of samples will be determined by the number of sampling zones identified and the variance among samples. Sampling zones will be different for oysters than for fish and crustaceans.

Oyster settlement and early survival

1) The number of oyster spat settling and surviving on a defined area will be used as an indicator of recruitment success.

2) Butler plates will be deployed in conjunction with the Nestier trays.

3) Measurements over time - plates will be replaced quarterly when Nestier trays are surveyed, and the number of spat will be recorded in the laboratory.

4) Measurements over space - spatial coverage and number of samples will be the same as for Nestier trays.

VII. PROJECT TYPES REQUIRING MONITORING

All CWPPRA projects have the potential for positive or negative impacts on fishery resources. Decisions as to the types of projects that should be monitored, however, should be based on the likelihood of these impacts, the time frame of expected impacts, and the difficulty in assessment of impacts. Project types have been grouped into the following categories:

Projects that definitely require impact assessment:
- Hydrological restoration
- Freshwater diversion
- Marsh management

Projects that require limited assessment (selected projects):
- Sediment diversion
- Beneficial uses of dredged material (including terracing)
- Sediment and nutrient trapping

Projects where assessment is unlikely to provide valuable information:
- Vegetative plantings
- Barrier island restoration
- Shoreline protection

VIII. HISTORICAL DATA

The Louisiana Department of Wildlife and Fisheries (LDWF) collects fishery samples at numerous stations throughout coastal Louisiana. The Field Procedures Manual, on file with the monitoring work group, identifies station locations and summarizes the variables being estimated, frequency of collection, and gear types in use.

Data collected in the LDWF fishery monitoring program are valuable in determining long-term trends and general abundance patterns of fishery species. In a broad-scale sampling program, variability in gear catch efficiency is more likely to simply increase variability among samples rather than cause biased estimates. In addition, the wide variety of gear types in use (each with its own specific catch efficiency characteristics), makes it unlikely that all samples will be biased in the same direction. In contrast to the large-scale sampling program of LDWF, sampling for CWPPRA projects must be designed on a smaller scale with specific hypotheses to be tested, and samples must be comparable in a variety of shallow-water habitats.

Therefore, the LDWF data base will be most useful in determining long-term fishery trends and assessing the comparability of control and project areas. In addition, these data should be valuable in assessing whether the overall abundance of fishery species for one specific year is abnormally high or low. This information will be important in comparisons of project area results before and after project implementation.

IX. PEER REVIEWERS

Barton Rogers	Louisiana State University
Carol Clark	Department of Natural Resources
Nancy Powell	U.S. Army Corps of Engineers
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James Gosselink	Louisiana State University
Edward Hickey	U.S. Soil Conservation Service
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