PNWD-3861

Pacific Northwest National Laboratory
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Monitoring and Adaptive Management Guidelines for Nearshore Restoration Proposals and Projects

R.M. Thom
N.K. Sather
M.G. Anderson
A.B. Borde

September 2007

Prepared for
the Puget Sound Nearshore Ecosystem Restoration Program (PSNERP) and the Estuarine Salmon Restoration Program (ESRP)
under a Related Services Agreement between
Washington Department of Fish and Wildlife
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Contract DE-AC05-76RL01830

PACIFIC NORTHWEST NATIONAL LABORATORY
operated by
BATTELLE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC05-76RL01830

Printed in the United States of America

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(9/2003)

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R.M. Thom
N.K. Sather
M.G. Anderson
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Marine Sciences Laboratory
Sequim, Washington

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Summary

This report provides monitoring and adaptive management guidance for practitioners conducting nearshore restoration projects in Puget Sound. The guidance was developed through a review of both national and regional documents that address the topics. The intention is to assist practitioners in improving the success of their projects, as well as improving the overall success of programs to restore Puget Sound ecosystems. We found that principles produced by the Puget Sound Nearshore Ecosystem Project (PSNERP) generally followed accurately the national guidance from groups such as the National Research Council as well as national experts. We found through interviews of practitioners of 11 projects in Puget Sound that PSNERP principles were not specific enough, and sometimes not clear enough, to implement by practitioners. In particular, there was a general uncertainty on how adaptive management should be carried out, and how to fund monitoring and adaptive management. Further, some PSNERP principles were not applicable to the individual projects. Finally, we provide guidance for a monitoring framework, which includes adaptive management that can be followed by practitioners. The framework includes the following eight components:

1. *Articulate the project goal*
2. *Develop the conceptual model*
3. *Choose the performance criteria and triggers*
4. *Choose monitoring parameters and methods*
5. *Categorize the types of data, data quality and management plan*
6. *Determine the level of effort, roles, duration, and cost*
7. *Conduct analysis, assess alternatives, report results*
8. *Make adjustments at project and program scales.*

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1.0 Introduction

1.1 Purpose

The purpose of our report is to provide monitoring and adaptive management guidelines for use by those proposing restoration projects for funding of estuarine salmon restoration projects. Building on existing overarching principles for monitoring (e.g., Busch and Trexler 2003) and adaptive management (NRC 2004) the Puget Sound Nearshore Ecosystem Restoration Project (PSNERP) Nearshore Science Team (NST) strongly felt the need to refine the principles to be more specific as guidelines. Among other uses, these guidelines will facilitate development of (1) criteria to rank proposals, and (2) the monitoring and adaptive management plan for the PSNERP General Investigation. The intent of the guidelines is not to develop specific protocols for monitoring and adaptive management, but to provide clear and simple guidance on *how* to develop a monitoring program at the project level. Among the considerations are keeping the guidance simple and easily and broadly applicable, reducing monitoring effort and cost, and assuring that the results of the monitoring programs contribute to both reducing uncertainties about projects and improving project success. Although protocols already exist (e.g., Simenstad *et al*. 1991) for many of the habitat types and metrics, modification and refinement of protocols should be an ongoing process driven by findings of the monitoring programs, as well as by new research and technology.

1.2 Background and Definitions

Justification for monitoring and adaptive management of restoration projects is well stated elsewhere (e.g., NRC 1992, 2004). Because restoration of aquatic systems is a relatively new science, and the systems being restored are complex and not well understood, there is less predictability of restoration actions. Project failures continue to occur. Further, restoration projects can be massively expensive. Clearly, there is a need to improve our understanding of how to design, build, and manage projects to meet their intended goals. Through monitoring, one assesses and finds ways to improve the effectiveness of a project in meeting its goal. In addition, monitoring provides information that can be used to better plan future projects. This process is not unlike that of an engineer who designs a bridge, evaluates its performance, and learns how to build better bridges. In medicine, evaluating the recovery of a patient after administering a remedy provides information that can improve the approach to treatment of the present and future patients. In practice, monitoring and adaptive management (defined as "learn by doing") are considered much less important and therefore, less fundable components of restoration projects. However, continued failures of expensive projects can ultimately result in reducing public support for both restoration and for the protection of ecosystems (e.g., Thom *et al.* 2005a).

Restoration monitoring is defined by Thayer *et al*. (2003) as "[t]he systematic collection and analysis of data that provides information useful for measuring project performance at a variety of scales (locally, regionally, and nationally), determining when modification of efforts is necessary, and building long-term public support for habitat protection and restoration." Monitoring relevant to restoration can be divided into three phases, as follows (Busch and Trexlor 2003):

1. **Implementation monitoring** – *track how a project is carried out through construction or other actions.* Assess during or immediately following the implementation aspects such as, for example, whether site elevations are correct as planned, the hydrology has been re-established as anticipated, etc.
2. **Effectiveness monitoring** – *track the progress of the project relative to its intended goals and objectives.* Assess whether the project is providing the ecological or other performance conditions, whether the project is maintaining the performance, and whether the trajectory of development of the ecosystem is at a rate and a direction intended.
3. **Validation monitoring** – *periodically review the ongoing program to validate the assumptions linking implementation and effects of projects.* Build the base of understanding upon which confidence in the effects of actions can be developed. For example, there is a growing understanding that through removal of dikes around former tidal marshes recovery of the marshes proceeds relatively rapidly toward a predictable outcome. If this observation were correct, it would validate the principle that the greater the reconnection, the faster the recovery rate.

Adaptive management was defined by Walters (1997) as "a structured process of learning by doing that involves more than simply better ecological monitoring and response to unexpected management impacts. It should begin with a concerted effort to integrate existing interdisciplinary experience and scientific information into dynamic models that attempt to make predictions about impacts of alternative policies." Adaptive management is used in circumstances where significant uncertainties exist and where actions and decisions must be made (Walters and Holling 1990). Therefore, the more systematic the adaptive approach, and the more integrated the adaptive management process is with the project, the greater the likelihood of improving the project's performance. There are very few restoration projects with little or no significant uncertainties.

Adaptive management can be conducted actively through a series of experiments, or passively by performing an action and monitoring the results. Essential elements of an adaptive management program for restoration projects are the goals of the project, a conceptual model, and a framework for decisions (Thom 2000). The goals drive what is designed and built, and the measures used to assess the performance of that which is constructed. The conceptual model organizes the understanding of the system and where within the system the goal is focused. The model also helps in selecting monitoring metrics (Van Cleve *et al.* 2004). It is important to establish the framework during the planning phase of the project. That is, establishing trigger points for decisions, alternative pathways, and follow-up investigations at the start of a project can facilitate its success. It also helps planners to specify the uncertainties, to determine how these will be addressed, and to predict the kinds of decisions that may result from the outcome of the project. The framework also specifies a schedule for assessing progress. Often, this involves annual meetings with key stakeholders. Another important piece of adaptive management is the dissemination of results. This is strongly encouraged to support further advancement of the state of the science of restoration.

The analysis of monitoring information and results from subsequent actions can provide benefit to both the project and the program. At the project scale, information from monitoring can indicate where adjustments need to be made to enhance project performance. This information may be of general use for planning future projects or making adjustment to existing projects. Project level results, if summarized in a systematic manner, form a valuable and growing knowledge base that can refine all phases of the projects from site selection through implementation and monitoring. Further, the learning process can extend to refinement of program goals and principles.

1.3 Objectives and Approach

To address the purpose of this report, we (1) reviewed the principles of monitoring and adaptive management provided by PSNERP (Goetz *et al.* 2004), (2) examined a sample of projects presently underway under the PSNERP purview, and other potentially relevant programs, and (3) wrote guidance on monitoring and adaptive management. We purposefully tried to simplify the monitoring guidance as much as possible to facilitate its use. Further, we incorporated the adaptive management components into the monitoring guidance to make them more accessible.

The Puget Sound program as it is implemented presently involves solicitation and screening of proposals for specific restoration projects of a wide range of types. Funding is generally small relative to major programs in a few other regions of the country (e.g., Louisiana, San Francisco Bay-Delta), and organizations proposing the projects often provide some level of monetary or in-kind match. This general approach to restoration is typical of many coastal regions (Van Cleve *et al.* 2004).

Perhaps the most relevant program of this type is that administered by the Lower Columbia River Estuary Partnership (a descendant of the Environmental Protection Agency National Estuary Program) in the Columbia River estuary. The Estuary Partnership receives funds from a few sources, solicits and reviews proposals from a wide array of entities, and manages the distribution of funds and tracking of project performance. The Estuary Partnership requires monitoring and reporting on projects. To facilitate assessment of progress in a systematic manner, it requires the use of a draft set of monitoring protocols. It is now in the process of formulating a way to conduct the restoration program in an adaptive management framework. Working concordantly with the Estuary Partnership's program is the Portland District of the U.S. Army Corps of Engineers (Corps). The Portland Corps has initiated a general investigation into estuary-wide habitat restoration. If fully implemented, the Corps' project would allocate substantial funds toward ecosystem restoration. Thus, in many key ways, the Columbia River estuary restoration program mirrors the pathway of the PSNERP.

PSNERP Monitoring and Adaptive Management Principles are listed here.

Monitoring principles:

1. *Project objectives should be used to build performance criteria and implement a monitoring program that evaluates attributes directly related to these criteria and the objectives they assess*
2. *Restoration actions should test hypotheses or answer specific questions about ecosystem functions and processes and human intervention. Monitoring provides the data to test the hypotheses*
3. *Monitoring should determine whether restoration goals are being met*
4. *Monitoring must be considered part of an information feedback system called adaptive management that leads to increased knowledge, which, in turn, reduces uncertainty in decision making and in the outcomes of restoration*
5. *Monitoring must be a long-term effort*
6. *Monitoring should be interdisciplinary*
7. *Monitoring should occur at multiple scales in time and space and selected indicators must be defined by objectives and be scaled appropriately*

8. *Monitoring must be inter-institutional owing to the complex nature of societal management of lands and natural resources*

<u>Adaptive Management Principles</u>:
1. *Adaptive management is employed to develop projects and to manage the restoration program, especially its goals and objectives*
2. *Adaptive management is best accomplished at large scales*
3. *Adaptive management is used to help reduce uncertainty and risk in implementing restoration actions and to increase knowledge about nearshore ecosystems*
4. *Adaptive management requires that all restoration actions be viewed, implemented, and monitored as a means to test hypotheses or answer questions posed by the conceptual model*
5. *An adaptive management approach is preferred where data are available at multiple steps and are used to structure a range of alternative response models*
6. *Environmental thresholds or triggers are essential in adaptive management*

The guidance herein is intended to help project managers conduct their projects. However, the lessons learned from the process should easily feed back into improving the approach to addressing the six overall goals of PSNERP (Gelfenbaum *et al.* 2006). The PSNERP goals are as follows:

1. *Rehabilitate ecosystem natural processes that create and maintain habitats in Puget Sound and watershed to fully support, with minimal ongoing human intervention, natural aquatic and associated terrestrial biotic communities and habitats in ways that favor native members of those communities*
2. *Protect and/or restore functional habitat types in Puget Sound nearshore and watershed for ecological and public values such as supporting species and biotic communities, ecological processes, recreation, scientific research, aesthetics, and other beneficial human uses*
3. *Prevent future listings and achieve recovery of at-risk native species dependent on Puget Sound as the first step toward establishing large, self-sustaining populations of these species; support similar recovery of at-risk native species in the Puget Sound and the watershed above the estuary; and minimize the need for future endangered species listings and reversing downward population trends of native species that are not listed*
4. *Prevent the establishment of additional non-native species and reduce the negative ecological and economic impacts of established non-native species in Puget Sound nearshore and watershed*
5. *Improve and/or maintain water- and sediment-quality conditions that fully support healthy and diverse aquatic nearshore ecosystems in Puget Sound and watershed; and eliminate, to the extent possible, toxic impacts to nearshore aquatic organisms, wildlife, and people*
6. *Increase the understanding of the natural processes and functions of the Puget Sound nearshore*

2.0 Existing Guidance Documents for Restoration Project Monitoring and Adaptive Management

Several documents over the past ~15 years have focused on the status of the Nation's environment, and they provide excellent, comprehensive treatments of the role and critical need for monitoring. These documents offer a national context for monitoring and adaptive management of nearshore restoration projects, and were used by us in the process of both evaluating the PSNERP principles listed in Section 1.3 and developing the specific guidance.

Restoring and Protecting Marine Habitat (NRC 1994)
The National Research Council (NRC) committee was asked to assess the needs for a coastal engineering strategy to preserve, protect, enhance, restore, and where necessary, create marine habitats to mitigate or reverse coastal marine habitat loss. They recommended the following points to advance the state of the practice of restoration, many of which directly guide monitoring and adaptive management:

- better understanding of ecosystem function
- promotion of policy and procedural change
- establishment of restoration goals and objectives
- cooperation among involved organizations, including integrated and collaborative actions
- collaboration of relevant scientific and engineering disciplines
- adapting technology and innovation through experimentation
- information transfer
- incentive-based solutions
- performance measurement.

Ecosystem Restoration in the Civil Works Program (Department of the Army 1995)
This somewhat obscure circular (No. 1105-2-210; expired 30 June 1997) is actually quite specific and profound in terms of guidance to Corps' staff on ecosystem restoration, monitoring, and adaptive management. The circular instructs staff to meet natural resource restoration objectives using an ecosystem approach by considering the roles of plant and animal species populations and their habitats in a larger context of community and ecosystem frameworks. Further, because of uncertainties, adaptive management should be considered for inclusion in restoration projects recognized to have potential for uncertainty in achieving their objectives. "At the heart of adaptive management, and the cornerstone for its success, is a carefully designed monitoring program that begins during construction and continues for a specific period after the project has been completed…Improving the knowledge base regarding a particular restoration approach or ecosystem component is a significant subset of the overall goal of adaptive management" (Department of the Army 1995).

Ecological Indicators for the Nation (NRC 2000)
The NRC was tasked with developing comprehensive ecosystem indicators that could be used to provide a status report on the health of the Nation's ecosystems. It used a set of criteria to screen potential indicators, and a conceptual model to organize the understanding of factors or stimuli to which these indicators would be responding, and to define aspects of ecosystem health to be

evaluated. Thirteen indicators were arranged into three categories, as follows: (1) extent and status of ecosystems (land cover, land use); (2) ecological capital (total species diversity, native species diversity, nutrient runoff, soil organic matter); and (3) ecological functioning or performance (carbon storage, production capacity, net primary production, lake trophic status, stream oxygen, nutrient-use efficiency, nutrient balance). Ideally, the metrics used to monitor restored sites link clearly, as appropriate, to these fundamental ecosystem indicators.

Adaptive Management of Renewable Resources (Walters 2001)
Carl Walters is one of the founders of adaptive management. This book largely deals with harvest of resources, and ways to better manage the harvests. The approach is mathematical in nature and relies on use of numerical models to assess uncertainties and to calculate effects of improvements in knowledge. Walters (2001) argued "that one possibility is to treat management as an adaptive learning process, where management activities are viewed as the primary tools for experimentation."

Compensating for Wetland Losses under the Clean Water Act (NRC 2001)
The NRC found that compensatory mitigation of wetland losses under the present wetland legislation was not being achieved. It provided five conclusions, with recommendations to improve the situation. Conclusion 3 stated that performance expectations have been unclear, and that compliance has not been assured. Among the recommendations were that projects need clear goals, implementation must be conducted correctly and documented through implementation monitoring, and functional assessments must be part of the effectiveness-monitoring program. Further, project management must be adaptive to improve project success.

The State of the Nation's Ecosystems (The Heinz Center 2002)
The Heinz Center report laid out a "blueprint for periodic reporting on the condition and use of ecosystems in the United States." Similar to the NRC's *Ecological Indicators* report, this report identified indicators arranged among four categories. The Heinz Center report further refined indicators within each of these categories for a number of ecosystem types. The most applicable ecosystem type for our purposes is coasts and oceans, for which the following indicators were recommended: (1) system dimensions (coastal living habitats, shoreline types); (2) chemical and physical conditions (areas with depleted oxygen, contamination of bottom sediments, coastal erosion, sea surface temperature); (3) biological components (at-risk marine native species, non-native species, unusual marine mortalities, harmful algal blooms, condition of bottom-dwelling animals, chlorophyll concentrations); and (4) human uses (commercial fish and shellfish landings, status of commercially important fish stocks, selected contaminants in fish and shellfish, recreational water quality). The report identifies significant data gaps in many of these indicators.

A National Strategy to Restore Coastal and Estuarine Habitat (Restore America's Estuaries 2002)
This report provides a nongovernmental agencies' plan for restoration of habitat in estuaries. Among its recommendations were that "evaluation progress in coastal and estuarine habitat restoration at the project, estuarine, and national scale is essential to long-term success." Further, it recommended tracking effectiveness of actions and using findings to design better and more effective projects.

Monitoring Ecosystems (Busch and Trexlor 2003)
This book provided a wealth of information ranging from importance of monitoring, principles of monitoring design, information management and modeling for monitoring programs, and monitoring various components of ecosystems. The book offered in-depth treatment that provides a useful context for site-specific monitoring guidance.

Adaptive Management for Water Resources Project Planning (NRC 2004)
This panel assessed ways in which adaptive management might usefully be applied in Corps' project planning and operations as part of a broader study conducted in response to a directive from Congress in Section 216 of the 2000 Water Resources Act. Nine recommendations, paraphrased here, were developed:

1. Post-construction evaluations should be standard practice in adaptive management
2. Stakeholder collaboration should be integral
3. Independent experts should periodically provide advice
4. Congress should establish a Corps Center for Adaptive Management
5. Congress should clarify water management objectives for the Corps
6. Congress should increase authority for the Corps to monitor and evaluate projects during post-construction
7. Congress should allocate funding to sustain the program
8. Congress should revise cost-sharing formulas to promote adaptive management
9. Administration should strengthen interagency coordination for large restoration programs.

Environmental Benefits and Performance Measures: Defining National Ecosystem Restoration and How to Measure its Achievements, a Discussion Paper (EAB 2006)
The Engineers Environmental Advisory Board (EAB) is a group of experts, independent of the Corps, who provide advice and guidance to the Corps at a national level. Most recently, the EAB has addressed issues surrounding ecosystem restoration. In this paper, the EAB described five topics and provided recommendations to the Chief of Engineers. Recommendations relevant to monitoring and adaptive management were (1) "…develop guidance …regarding the development and application of performance measures… [that]…specifically identify the differences between performance that the Corps' actions directly impact and those expected outcomes which may be influenced by external factors." Further, (2) "The Corps should continue to work with other Federal agencies with interests in ecosystem restoration to identify regional goals for restoration and develop common metrics to assess outcomes of ecosystem restoration investments."

Documents that provide more specific guidelines and approaches for monitoring coastal restoration projects include the following:

Estuarine Habitat Assessment Protocol (Simenstad *et al.* 1991)
This document provided the most comprehensive set of protocols for monitoring Puget Sound habitats. Most of the protocols are well suited for monitoring restored sites. An important aspect of the document is that it used published data to link habitat attributes (e.g., species abundances, prey taxa) to a set of common habitat types. These attributes, which are often easier to sample

than are functional attributes (e.g., productivity, growth), can serve as scientifically defensible surrogate indicator metrics for functional attributes.

Planning Aquatic Ecosystem Restoration Monitoring Programs (Thom and Wellman 1996)
This report was prepared to provide a unified approach to planning, implementing, and interpreting monitoring programs for restoration efforts. The report was written specifically for Corps' planners to help them identify factors to consider in designing and implementing an efficient, cost-effective monitoring program. Monitoring is focused on the assessment of performance relative to a goal. A conceptual model provides the basis for selection of parameters to monitor. We used much of the guidance from this report in the present guidance.

Science-based Restoration Monitoring of Coastal Habitats. Volume One: A Framework for Monitoring Plans Under the Estuaries and Clean Water Act of 2000 (Public Law 160-457) (Thayer *et al.* 2003)
This document provided the National Oceanic and Atmospheric Administration's (NOAA) guidance on establishing monitoring programs for coastal restoration projects. It covered stages in monitoring plans, a 12-step process to create a monitoring plan, and important information that should be considered when monitoring specific habitats. We used much of the information in this report in conjunction with Thom and Wellman (1996) in developing the guidance.

3.0 Synthesis of Projects Reviewed

3.1 Approach

For the purpose of determining the role of monitoring and adaptive management in estuarine and nearshore restoration we used the Salmon Recovery Funding Board (SRFB) project database, PRISM, to identify candidate projects to be included in our review. Criteria for selecting projects included project type, location, and status. Although the SRFB supports many projects that include restoration, property acquisition, maintenance, and education, our focus was identifying completed estuarine and nearshore restoration projects within the Puget Sound and Hood Canal basins. Additionally, with guidance from PSNERP, we identified a secondary list of completed nearshore restoration activities implemented independently of SRFB projects. We received responses from 11 projects of the 15 that were selected (Table 1).

Table 1. Nearshore and estuarine restoration projects selected for adaptive management interviews

Region	***Project Title***	***Response Provided***
	SRFB Projects	
Skagit County	Deepwater Slough Revegetation	√
	McElroy Slough Estuary Restoration	√
	Spartina Control in Skagit Co. Estuaries	√
	Spartina Management of Skagit Bay	√
Kitsap County	Dogfish Creek Estuary Bridge	
	Sinclair Inlet North Shore Estuary Restoration	√
	Liberty Bay Nearshore Habitat Evaluation	
Island County	Crescent Bay Salt Marsh/Salmon Habitat Restoration	√
Hood Canal	Shine Estuary Restoration	
Nisqually	Nisqually Estuary Restoration	
	Non-SRFB Projects	
Central Sound	Seahurst Park Restoration	√
South Sound	Woodard Bay (Weyer Point) Restoration	√
Skagit County	Deep Water Slough	√
North Sound	Clinton Ferry Terminal Eelgrass Restoration	√
Snohomish County	Spencer Island-Snohomish	√

We submitted the following questions to restoration project managers as a way to initiate the interview:

1. Prior to restoration, what adaptive management principles were proposed for your project?
2. What adaptive management principles were actually applied?
3. How was adaptive management used/applied?
4. Did the project use current PSNERP adaptive management principles?
5. Did the project contain a monitoring component?

3.2 Results

None of the 11 projects that returned responses or participated in interviews used all of the PSNERP monitoring principles (Table 2). The number of the principles used ranged from 0 – 7, with an average of ~3 per project. The most frequently applied principles were Numbers 3 (monitoring determines whether goals are met) and 4 (monitoring linked to adaptive management). Least frequently applied were principle Numbers 5 (long-term monitoring) and 7 (spatial and temporal monitoring regime; indicators must be defined by objectives). Principle Number 7 had the most "unknown" responses, indicating either that the respondent did not know whether it had been applied, or it was difficult to discern whether it had been applied.

Similarly, none of the 11 projects that returned responses or participated in interviews used all of the PSNERP adaptive management principles (Table 3). The number of principles followed ranged from 0 – 4, and 7 of the 11 projects used only one principle. Principle Number 8 (participation of science, monitoring, and management to make decisions) was used most frequently (i.e., 7 of the 11 projects). Principle Numbers 2 (adaptive management is best at program level), 5 (adaptive management uses data throughout all phases), 6 (understanding threshold or triggers), and 7 (applied the precautionary principle) were not used. Principle Numbers 6 and 7 had the most "unknown" responses. Since we reviewed projects only, it was logical that Principle Number 2 (adaptive management is best conducted at the program level was not applicable to any of the projects.

3.3 Case Studies

As part of the nearshore restoration process, several of the projects reviewed during this exercise demonstrated use of both monitoring and adaptive management principles. Compared with monitoring plans, adaptive management was incorporated into the restoration planning phase to a lesser degree. In speaking with project managers about their nearshore or estuarine restoration projects it became apparent that in some cases, monitoring results were causing managers to assess and re-evaluate project goals. Projects with monitoring and/or adaptive management plans have been highlighted as Case Studies below. Published project monitoring plans utilized during our review process are included as a separate appendix to this document.

Selected examples of projects using monitoring and adaptive management principles include the following case studies:

Deep Water Slough

The Deep Water Slough restoration project sought to reestablish riverine and tidal hydrologic connectivity through the removal of dike material. Prior to restoration actions a monitoring plan was developed for the site. This plan is laden with project goals, objectives, and restoration actions and outlines the collaboration, work involvement and responsibilities for participating agencies. The proposed monitoring tasks outlined by the Deep Water Slough plan included surveying, characterizing and/or inventorying the following parameters: hydrology, channel morphology, topography, vegetation, sediment accretion, water and sediment quality, salmonid use, invertebrates, amphibians, migrating birds, waterfowl breeding activity, shorebirds, and small mammals (Klochak et al. 1999). While the monitoring plan included the appropriate

Table 2. PSNERP monitoring principles (as applied to the projects that were reviewed)

	1	2	3	4	5	6	7	8
Project Name	Objectives linked to performance criteria	Monitoring designed to test hypotheses	Monitoring determines whether goals are met	Monitoring linked to adaptive management	Long-term monitoring (>5years)	Interdisciplinary monitoring	Spatial and temporal monitoring regime; indicators must be defined by objectives	Inter-institutional monitoring
Deepwater Slough Revegetation	U	U	+	+	0	U	0	U
McElroy Slough Estuary Restoration	+	+	+	+	NA	U	U	U
Spartina Control in Skagit Co. Estuaries	+	U	+	+	U	0	U	U
Spartina Management of Skagit Bay	+	U	+	+	U	0	U	U
Sinclair Inlet North Shore Estuary Restoration	0	0	0	0	0	0	0	0
Crescent Bay Salt Marsh/Salmon Habitat Restoration	U	U	NA	0	NA	U	U	+
Seahurst Park Restoration	0	U	U	0	0	+	U	+
Clinton Ferry Terminal	+	+	+	+	+	+	+	U
Deep Water Slough	U	U	+	+	0	+	U	+
Spencer Island-Snohomish	0	+	+	+	0	+	U	U
Woodard Bay	0	U	U	0	0	+	U	+
Liberty Bay Nearshore Habitat Evaluation	NR	NR	NR	NR	NR	NR	NR	NR
Dogfish Creek Estuary Bridge	NR	NR	NR	NR	NR	NR	NR	NR
Shine Estuary Restoration	NR	NR	NR	NR	NR	NR	NR	NR
Nisqually Estuary Restoration	NR	NR	NR	NR	NR	NR	NR	NR

\+ addressed by project
0 not addressed by project
U unknown, information not provided by interview
NA not applicable
NR no response

Table 3. PSNERP adaptive management principles (as applied to the projects that were reviewed)

	1	2	3	4	5	6	7	8
Project Name	AM is part of the program	AM is best at a program level	AM used to reduce uncertainty and risk prior to implementation	All restoration activities are conducted to test hypotheses	AM uses data throughout all phases to structure multiple response models	Understanding thresholds or triggers	Applied the precautionary principle when necessary	Participation of science, monitoring, and management to make decisions or change approach based on lessons learned
Deepwater Slough Revegetation	0	NA	U	0	0	U	U	+
McElroy Slough Estuary Restoration	+	NA	U	0	U	U	U	+
Spartina Control in Skagit Co. Estuaries	0	NA	U	0	U	U	U	+
Spartina Management of Skagit Bay	0	NA	U	0	U	U	U	+
Sinclair Inlet North Shore Estuary Restoration	0	NA	0	0	0	U	U	0
Crescent Bay Salt Marsh/Salmon Habitat Restoration	0	NA	+	0	U	U	U	NA
Seahurst Park Restoration	0	NA	+	0	U	U	U	U
Clinton Ferry Terminal	+	NA	+	+	U	U	U	+
Deep Water Slough	0	NA	U	0	U	U	U	+
Spencer Island-Snohomish	0	NA	U	0	0	U	U	+
Woodard Bay	0	NA	0	0	0	U	U	U
Nisqually Estuary Restoration	NR	NR	NR	NR	NR	NR	NR	NR
Liberty Bay Nearshore Habitat Evaluation	NR	NR	NR	NR	NR	NR	NR	NR
Dogfish Creek Estuary Bridge	NR	NR	NR	NR	NR	NR	NR	NR
Shine Estuary Restoration	NR	NR	NR	NR	NR	NR	NR	NR

AM Adaptive management
+ addressed by project
0 not addressed by project
U unknown, information not provided by interview
NA not applicable
NR no response

12

framework for linking physical processes to biological responses the majority of the monitoring tasks were never funded. The limited monitoring conducted at the Deep Water Slough restoration site was a result of creatively pooled funding sources (Greg Hood, personal communication, July 2007).

Following restoration activities at the Deep Water Slough restoration site, pre- and post-restoration monitoring revealed the need to remove invasive species and to plant native vegetation at the project site. Using data collected on site, a model incorporating elevation data was developed to determine vegetation types that were more appropriate at a given elevation. Experimental manipulation was conducted by removing invasive plants and as the model indicated, native vegetation has begun to establish in areas formerly occupied by invasive cattail plants (Greg Hood, personal communication, July 2007). Further manipulation at this restoration site has involved experimental planting to determine the most appropriate techniques for establishing a marsh shrub, sweetgale (Perry Welch, personal communication, July 2007).

McElroy Slough

In Northern Puget Sound, McElroy Slough flows through numerous lowland areas surrounding the community of Blanchard before terminating in Samish Bay. The primary goal of the McElroy Slough restoration project was achieved in 2006 when saltwater was reintroduced to the slough following installation of a self-regulating tide gate. The importance of McElroy Slough for providing salmon habitat is demonstrated through its connectivity with several salmon bearing creeks. Prior to project implementation, a monitoring plan was initiated to collect baseline data related to surface and ground water levels, and salinity. It was anticipated that the project would start in 2002, but unanticipated political and engineering concerns surrounding tide gate replacement postponed project implementation for 4 years. Despite a delay in restoration activity, monitoring of the site continued during that time. In 2006, the project resumed and three existing culverts were replaced with tide gates. Before construction commenced, the Skagit Fisheries Enhancement Group (SFEG) implemented components of the monitoring plan to collect baseline data both inside and outside of the tide gate. Other activities included documenting juvenile fish usage, channel cross sections, establishment of vegetation plots, and an aerial imagery to document baseline conditions. Post construction monitoring was initiated and community members along with SFEG have been engaged to ensure effectiveness monitoring is carried out at the site as outlined in the original monitoring plan (Studley 2007).

Spartina Management

Our review of project level restoration revealed *Spartina* eradication in nearshore habitats used monitoring to determine the effectiveness of removal strategies. When the current strategy (e.g., herbicide spraying) does not prove useful, other methods deemed appropriate for the site are implemented (e.g., mowing, digging, and biological removal agents) (Will Rogers, personal communication, July 2007; Alison Studley, personal communication, July 2007).

The management of an invasive cord grass, *Spartina* in Washington State presents several interesting examples of interagency cooperation as well as the difference between program level and project level management practices. The state wide monitoring program for *Spartina* is administered by the Washington State Department of Agriculture (WSDA) and is comprised of three regional management groups; Willapa Bay, Grays Harbor, and Puget Sound. A statewide *Spartina* management plan including goals and benchmarks exists, however the degree of interagency cooperation at the project level requires the plan to maintain a certain degree of fluidity (WSDA 2005; Chad Phillips, pers. comm. August 2007).

While large scale planning and management of *Spartina* is administered by WSDA, project level eradication/restoration efforts are performed through interagency cooperation. County and Tribal governments, University entities, non profit groups such as The Nature Conservancy, as well as state agencies including Washington Department of Fish and Wildlife, Washington Department of Natural Resources, and Washington State Park Service are a sampling of groups that have coalesced under the program level management of *Spartina* in Washington State (Chad Phillips, pers. comm. August 2007).

Monitoring and management occurs at both the program and project level. The ability to accomplish the ultimate goal of *Spartina* eradication is largely dependent on available funding from federal and state sources, as well as other grant opportunities (Murphy et al. 2007). Once *Spartina* has been observed at a site and eradication efforts are taken, follow-up monitoring occurs at the treated site once each year, until observations indicate eradication has been successful (Chad Phillips, pers. comm. August 2007). For the 2007 monitoring season, WSDA has secured funding to conduct an aerial survey to monitor the coast line of Washington State with the aim of covering areas that have not been previously surveyed.

Woodard Bay-Weyer Point Site Restoration

Located in Southern Puget Sound, the Woodard Bay-Weyer Point restoration project removed nearly 250 feet of bulk head material from the shoreline, and included the removal of anthropogenic structures from the site. Pre-restoration monitoring included a multi-agency collaboration effort to collect data and analyze physical site characteristics (Gerstel 2005). Monitoring efforts included vegetation, sediment analysis, elevation profiles, and invertebrate sampling (Michelle Zukerberg, pers. comm. July 2007). A monitoring plan was developed for the Woodard Bay-Weyer Point restoration site. Aside from on the ground photo documentation, the inability to adequately fund post-restoration monitoring has prevented most of the monitoring action items from being implemented (Michelle Zukerberg, pers. comm. July 2007).

The Woodard Bay-Weyer Point monitoring plan serves as a template for other projects in that it outlines project objectives as well as questions intended to be answered at multiple time scales. The monitoring protocols are supplemented with specific methods for implementing sampling efforts. Further, the monitoring plan was embedded with a timeline to streamline sampling effort following restoration actions (Gerstel 2006).

Clinton Ferry Terminal
The mitigation efforts aimed at reducing the impacts of the Clinton Ferry Terminal expansion project on eelgrass habitats has involved ten years of post-construction monitoring. The initial Mitigation Plan outlines project goals, anticipated results (i.e. performance criteria), and provides a framework for post-construction environmental monitoring (Thom et al. 1995). The coupling of adaptive management and long-term monitoring efforts has allowed management agencies to adjust project activities, methods, and performance criteria to achieve project goals (Vavrinec et al. 2007). Annual meetings and reports involving technical and management teams provides a forum for information dissemination and learning. Through its commitment to continued monitoring, Washington State Department of Transportation has created a unique and unprecedented regional opportunity for long-term monitoring of nearshore ecosystems.

Spencer Island
In an effort to reconnect tidal flow to a diked area, the Spencer Island restoration project used monitoring results to assess the functional performance of the restored system. In one case, the presence of an invasive species resulted in managers' introducing a beetle as a biological control agent. Further, despite original objectives of restoring the area to a brackish marsh, the progression of the Spencer Island restoration site to a tidal freshwater marsh was accepted by managers because the net outcome achieved desirable ecosystem function (Tanner *et al.* 2002).

Project goals and objectives for the Spencer Island restoration site are outlined by Tanner (1993). A comprehensive monitoring plan linking the project goals and objectives with specific monitoring protocols was created to help managers collect the necessary data for determining ecological change following restoration at the Spencer Island restoration site (Tanner 1993; Table 4). For each of the monitoring protocols the Spencer Island plan clearly outlines the following parameters:

- Level of monitoring
    - (e.g. minimum, preferred, recommended)
- Project Performance Indicators
    - Links monitoring protocol to project objectives
- Sampling Design
    - a succinct description for designing the monitoring task
- Data Collection Protocol
    - a succinct description for executing the monitoring task
- Implementation Schedule
    - Suggests sampling frequency and duration
- Data Analysis
- Report Format
- Equipment and Supplies
- References

The level of organization coupled with the holistic approach of linking goals, objectives, performance criteria and monitoring protocols within the Spencer Island Monitoring Plan provides an appropriate example and useful tool for other Puget Sound nearshore restoration projects.

Table 4. Example of a monitoring protocol matrix linking project goals, objectives, and performance criteria to specific monitoring protocols (adapted from Tanner 1993).

				Monitoring Protocol												
Goal	Objective	Performance Criteria	Performance Indicator	Tide gauge	Current Velocity	Aerial photo	Elevation survey	Vegetation biomass	Forested community	Waterfowl survey	Sedentary fish	Motile fish	Surface epifauna	Epibenthic plankters	Neustonic/drift invertebrates	Water quality
Re-establish tidal conditions to 50 acres	achieve normal tidal fluctuations	NP	Tide flux	x												
Re-establish tidal conditions to 50 acres	Diminish excessive current velocities	NP	Velocity		x											
Re-establish tidal conditions to 50 acres	Inundate 50 acres of marsh	NP	Area			x	x									
Re-establish tidal conditions to 50 acres	achieve typical tidal marsh geomorphology	NP	Geomorphology			x	x									
Increase habitat diversity	Increase structural diversity	decrease area of reed canarygrass	RCG area			x		x	x							
Increase habitat diversity	Increase structural diversity	Increase intertidal habitat communities	Intertial community area	x		x	x	x	x							
Increase habitat diversity	Increase species diversity	NP	species diversity							x	x	x				
Improve habitat quantity and quality for estuarine fishes	Increase habitat area	Increase fish access to southern portion of the site	Fish access								x	x				
Improve habitat quantity and quality for estuarine fishes	Improve habitat quality	Increase habitat attributes for juvenile salmon (e.g. prey resources and habitat structure)	Attributes										x	x	x	
Improve habitat quantity and quality for estuarine fishes	Improve habitat quality	NP	Water Quality													x

NP: performance criteria not provided

3.4 Conclusions

Our interviews revealed that most projects evaluated included some form of monitoring. However, the use of monitoring results to assess project goals was evident in only 64% of the projects. The success of adaptive management relies on the existence of a project monitoring plan. During our interview process, we noted that many restoration projects relied on monitoring from agencies or funding sources independent of the Salmon Recovery Funding Board. Individuals familiar with adaptive management principles expressed frustration about the lack of funding opportunities available to adequately monitor restoration projects. In the absence of monitoring, the project success will be unrealized, as will the dissemination of learning opportunities afforded by nearshore and estuarine restoration projects. Many project managers interviewed were unaware of adaptive management, and although others were vaguely familiar with the term, they expressed uncertainty about its application and value. Despite the lack of sound adaptive management strategies applied to many of the reviewed projects, a few projects demonstrated the use of some adaptive management principles.

4.0 Review of PSNERP Monitoring and Adaptive Management Principles

A goal of our review is to develop guidance on how to apply the principles developed by PSNERP to projects. Based on the review of projects, monitoring and adaptive management are applied unevenly across local publicly funded restoration projects. Our assessment of PSNERP principles relied heavily on the national guidance material cited above and on our own experience. Our experience ranges from development of monitoring protocols for Puget Sound (Simenstad *et al.* 1991) and the Columbia River estuary (Roegner *et al.* 2006), to restoration project monitoring (e.g., Simenstad and Thom 1996, Thom *et al.* 2005b), and assistance in developing national guidance documents (Thom and Wellman 1996; Thom 1997, 2000, Thom *et al.* 2005a, Diefenderfer *et al.* 2005; Borde *et al.* 2007). In addition, we are currently working with the Columbia River Estuary National Estuary Program and the Portland District of the Corps to develop adaptive management within their restoration programs. Through this applied experience, we have developed a working knowledge of how monitoring and adaptive management can be effectively conducted in coastal and estuarine habitat restoration projects and programs.

In Table 5 and Table 6, we assess how well the PSNERP principles agree with what we refer to as national guidance documents. Overall, we believe that the monitoring and adaptive management principles provided by PSNERP fit well with both national guidance and practical experience in the Northwest. However, there are two points common to the national guidance documents and the PSNERP principles that reflect a general gap in application. First, the documents are intended primarily to provide recommendations at a level of treatment above that which a practitioner might apply to a project. Thus, they lack specificity needed by practitioners. Although the principles are based on the literature, their specific application to projects is not always obvious. The results of our review of projects confirmed this view. Second, although there are specific monitoring protocols (e.g., Estuarine Habitat Assessment Protocol [Simenstad *et al.* 1991]) for many regions, it is very rare to find specific protocols for applying adaptive management principles at the project level. There needs to be a link between the specific monitoring protocols and adaptive management.

In our review, the two least-used principles for monitoring were Numbers 5 and 7 (Table 5). For Number 5 (project monitoring should be long-term), we suggest that the commitment of adequate funding was the primary impediment. We wondered whether the commitment by the implementing agency and institutional constraints were also causal factors. National guidance strongly recommends long-term monitoring as dictated by the system type, spatial scale, uncertainty, risks, and a variety of other factors. This principle is probably the most troublesome issue at the national and international level in the science of restoration. Principle Number 7 (monitoring at multiple scales) probably was infrequently applied because of lack of funding. Hence, project monitoring was kept as simple and inexpensive as possible. We wondered whether lack of understanding of the principle was a contributing factor; the meaning of the principle was not immediately obvious to us, as informed readers and scientists. We found Principles 1 and 3 to be similar. Both relate to monitoring to meet some goal or objective, and both are best assessed against some set of criteria. Perhaps they could be combined.

Table 5. Summary of PSNERP monitoring principles, their fit with national guidance, their local application in projects reviewed, and recommendations for implementation

PSNERP Principle	Fit with National Guidance Documents	Application in Local Reviewed Projects (% of total)[(a)]	Summary of Application Guidance (Step no.)[(b)]
1. Project objectives should be used to build performance criteria and implement a monitoring program that evaluates attributes directly related to these criteria and objectives they assess.	This principle is cited as critical.	36%	• State the goal for the project (1) • Refine the goal to a set of clear objectives (3) • Select the metrics to measure that clearly link to the goal and objectives (4) • Define the performance criteria for each metric (3)
2. Restoration actions should test hypotheses or answer specific questions about ecosystem functions and processes and human interventions. Monitoring provides the data to test the hypotheses.	This principle is infrequently cited for site-specific projects, but is recommended at the program level or if resolving uncertainties are critical to a project outcome. Requires that restoration be performed as an experiment.	27%	• Identify uncertainties and/or hypothesis critical to project or program up front in project planning (2) • Construct hypotheses that can be addressed by the project (3) • Design project and monitoring to collect data that directly address hypotheses (3, 4) • Incorporate appropriate reference sites and control sites (4)
3. Monitoring should determine whether restoration goals are being met.	This principle is cited as critical.	64%	• See guidance for Principle No. 1 above
4. Monitoring must be considered part of an information feedback system called adaptive management that leads to increased knowledge, which, in turn, reduces uncertainty in decision making and in the outcomes of restoration.	Explicit, critical principle in recent guidance. Implicit principle in earlier literature.	64%	• See guidance for Principle No. 2 above • Develop a framework for incorporating information into decisions on project implementation and management (7, 8) • Disseminate information to others (7, 8)
5. Monitoring must be a long-term effort.	Monitoring duration must be sufficient to assess performance. Most restored estuarine systems do not reach stability in <5 years.	9%	• Specify duration and justify based on expected time to reach the goal or criteria, and be relatively stable (4) • Or, specify when the trajectory of development should indicate that the system is progressing toward the criteria or goal (3)
6. Monitoring should be interdisciplinary.	As projects become more complex, they often are more costly, have greater uncertainties, and require specific expertise.	46%	• Consider the metrics to be monitored, and the level of expertise required (3, 4) • Evaluate data analysis and interpretation needs (5) • Acquire commitments from team members (6)
7. Monitoring should occur at multiple scales in time and space and selected indicators must be defined by objectives and be scaled appropriately.	Monitoring frequency and timing must be sufficient to assess performance. Sampling design is critical. Broader regional program goals require greater spatial scales.	9%	• Develop the sampling design based on temporal dynamics and spatial patterns of monitoring metrics (4)
8. Monitoring must be interinstitutional owing to the complex nature of societal management of lands and natural resources.	Acknowledged as necessary to address funding and regulatory mandates, but not critical to all projects.	36%	• When planning monitoring, consider agencies and institutions that could have jurisdiction or direct interest and expertise in the project (3, 6, 7, 8) • Consult with knowledgeable person to identify critical institutions and individuals within institutions (6, 7, 8)

(a) The percentages of application in local reviewed projects data are from Table 2.
(b) 'Step no.' refers to steps in Section 5 (monitoring framework) below where points are addressed.

Table 6. Summary of PSNERP adaptive management principles, their fit with national guidance, their local application in projects reviewed, and recommendations for implementation

PSNERP Principle	Fit with National Guidance Documents	Application in Local Reviewed Projects (% of total)[a]	Summary of Application Guidance (Step no.)[b]
1. Adaptive management is employed to develop projects and to manage the restoration program, especially its goals and objectives.	The adaptive management framework should be integral to the project in order to maximize the success of the project, and provide information to additional projects.	18%	• Establish the goals, performance objectives and criteria up front (1, 2, 3) • Clearly identify uncertainties and how these will be addressed, if at all (2, 3) • Identify an risks associated with uncertainties (2, 3) • Identify trigger points for decisions as well as potential alternative decisions (3)
2. Adaptive management is best accomplished at large scales.	If possible, restoration programs should be designed to systematically evaluate critical uncertainties, and develop specific actions using suites of projects.	0%	• Project actions should assist is answering program questions, and improving program success (8)
3. Adaptive management is used to help reduce uncertainty and risk in implementing restoration actions and to increase knowledge about nearshore ecosystems.	See Principle No. 2	27%	See Principle No. 2
4. Adaptive management requires that all restoration actions be viewed, implemented, and monitored as a means to test hypotheses or answer questions posed by the conceptual model.	A conceptual model is critical to an adaptive management program, and organizes the understanding of the system to be restored. The model helps identify uncertainties that need investigation. The model is improved through information from projects.	9%	• Develop a conceptual model (2) • Highlight relevant uncertainties in the model (2, 3) • Design monitoring to evaluate uncertainties (3, 4, 5) • Revise the model, as needed, when data are available (2, 8)
5. An adaptive management approach is preferred where data are available at multiple steps and are used to structure a range of alternative response models.	The process is ongoing, and relies on knowledge gained through actions. As uncertainties are addressed, new uncertainties often arise, which require further investigation. Some uncertainties require several steps to fully investigate.	0%	• Identify clearly the decision process (8) • At each annual meeting, review results and decide on actions (7, 8)
6. Environmental thresholds or triggers are essential in adaptive management.	Triggers are a critical component. Triggers can be qualitative or quantitative.	0%	See Principle No. 1
7. If there are "irreducible uncertainties regarding causal relationships," the Precautionary Principle should be exercised.	Uncertainty is the lack of knowledge. Risk is potential to do harm. If uncertainties pose a significant risk to humans or the environment, precautions must be implemented.	0%	See Principle No. 1 • At each annual meeting, review risks and formulate precautions (7, 8)
8. Adaptive management requires the participation of science, monitoring, and management institutions, and the flexibility to take corrective measures and change an approach based on lessons learned.	Individual project information, if developed systematically to investigate uncertainties, should be used to inform science-based management decisions to improve program performance.	64%	• Involve stakeholders and program managers in the annual meeting (7, 8) • Clearly identify lessons learned that might drive potential changes to the program (7, 8)

(a) The percentages of application in local reviewed projects data are from Table 3.
(b) 'Step no.' refers to steps in Section 5 (monitoring framework) below where points are addressed.

Adaptive management principles followed national guidance documents well (Table 6). Principle Numbers 2, 5 and 7 were somewhat confusing to us, and also may have been to the practitioners, which resulted in lack of application to projects. In the right column of Table 6, we provide a list of points that should clarify the meanings and allow these principles to be applied at the project level. A premise of adaptive management is that the process be systematic. This can be highly rigorous, but in the great majority of projects, practical application of rigorous hypotheses testing is infeasible. We wondered whether conceptual models were used in the design for projects. This element is often cited as critical for designing and assessing restoration projects, and it provides a basis for uncertainty identification.

In Table 5 and Table 6, we list a set of points that are used later to develop guidance for project monitoring and adaptive management as related to each principle. These are meant to make the principle applicable during projects of a relatively wide range of sizes. We elaborate on these in the Section 5.0 below.

5.0 Guidance for a Monitoring Framework for Habitat Restoration Projects in Puget Sound

5.1 Objective

The purpose of this guidance is to provide specific and succinct step-by-step instructions for developing a restoration site monitoring plan conducted in an adaptive management framework (abbreviated as the ***monitoring framework***). Monitoring is required to assess the progress of a project toward its goal, and to provide information that could explain why the project may not be meeting expectations. The key question the restoration project manager must ask is, "What do I absolutely have to know to maximize my ability to manage the project toward its goal?" Using adaptive management, project managers and stakeholders make informed decisions on how to improve project performance. Ultimately, the information gained on each project will provide practical guidance toward the design and implementation of future restoration projects. Monitoring in an adaptive framework need not be excessively costly, if it is planned well. One goal of this guidance is to provide a method to streamline monitoring, while still providing adequate information to meet the purpose of a monitoring program. This monitoring guidance largely follows national guidance for monitoring aquatic restoration sites prepared for the Corps' Institute for Water Resources (Thom and Wellman 1996).

5.2 Components

The eight components of the monitoring framework are as follows:

1. *Articulate the project goal*
2. *Develop a conceptual model*
3. *Choose performance criteria and triggers*
4. *Choose monitoring parameters and methods*
5. *Categorize the types of data, data quality, and management plan*
6. *Determine the level of effort, roles, duration, and cost*
7. *Conduct analysis, assess alternatives, report results*
8. *Make adjustments at project and program scales.*

These components are referred here to as ***steps*** that must be developed during project planning phase.

Step 1. *Articulate the project goal*

The goals of the project *drive* the monitoring program. Hence, the goal is critical to the project and the monitoring that is conducted. Make the goal as simple and unambiguous as possible. Relate the goals directly to the vision for the project. Finally, establish a goal or set of goals that can be feasibly measured or assessed in a monitoring program. Often actual goals are not possible to measure directly. In this case, the goal is assessed through relevant performance criteria and metrics as described in Steps 3 and 4 below. As an example, the goal for the Clinton Ferry Terminal Eelgrass Project (Thom et al. 2005b) was to *have the overall project of terminal reconstruction and ferry boat operations result in no net loss of eelgrass*.

Step 2. ***Develop a conceptual model***

There are two basic conceptual models that can assist in development of the monitoring program. They are termed here the *habitat-based model*, and the *restoration-based model*. The habitat-based model defines the connections between the habitat that is the subject of the restoration project and the key factors it depends upon for its formation and maintenance. In addition, the model supplies connections between the habitat and its functions. Functions of habitat are often the goal of a project. The restoration-based model defines the connections between the potential actions to reduce or eliminate stressors to the habitat and the factors that form and maintain the habitat. These two models succinctly summarize the basic scientific understanding and critical guidance on what to monitor. Both provide a framework for determining project implementation and restoration action effectiveness. Stressors to the habitat generally act at the level of the controlling factors. Hence, the link between the habitat-based model and the restoration-based model is at the connection between the stressors and controlling factors. Finally, during the construction of the models key uncertainties are identified. In the eelgrass meadow example below, uncertainties may exist in linkages between some controlling factors and the habitat, between the habitat and some functions, or between the restoration actions and the nearshore processes.

Habitat-based model. In its most basic form, the habitat-based conceptual model should link the project-specific goal to the metrics and parameters used to assess the performance. The format of the model should be kept simple, but include all important factors. A useful format is the following:

Controlling factors ---> Habitat structure ---> Functions

Controlling factors commonly include elevation, sediment type, salinity range, etc. The range in factor values should be known. For example, if the goal is to restore a functional eelgrass meadow, the planner needs to know at what elevation and under what salinity range eelgrass grows most abundantly (Figure 1). The better the understanding of the key controlling factors for the target habitat type, the better the chance that a site assessment will reveal the critical aspects for restoration to assure that an eelgrass meadow develops. Further, the model will assist in identifying the monitoring metrics. It is appropriate to simply list the controlling factors along with their ranges for the target habitat type. If one or more have overriding importance (e.g., elevation or depth), then those should be highlighted as the factors requiring more attention.

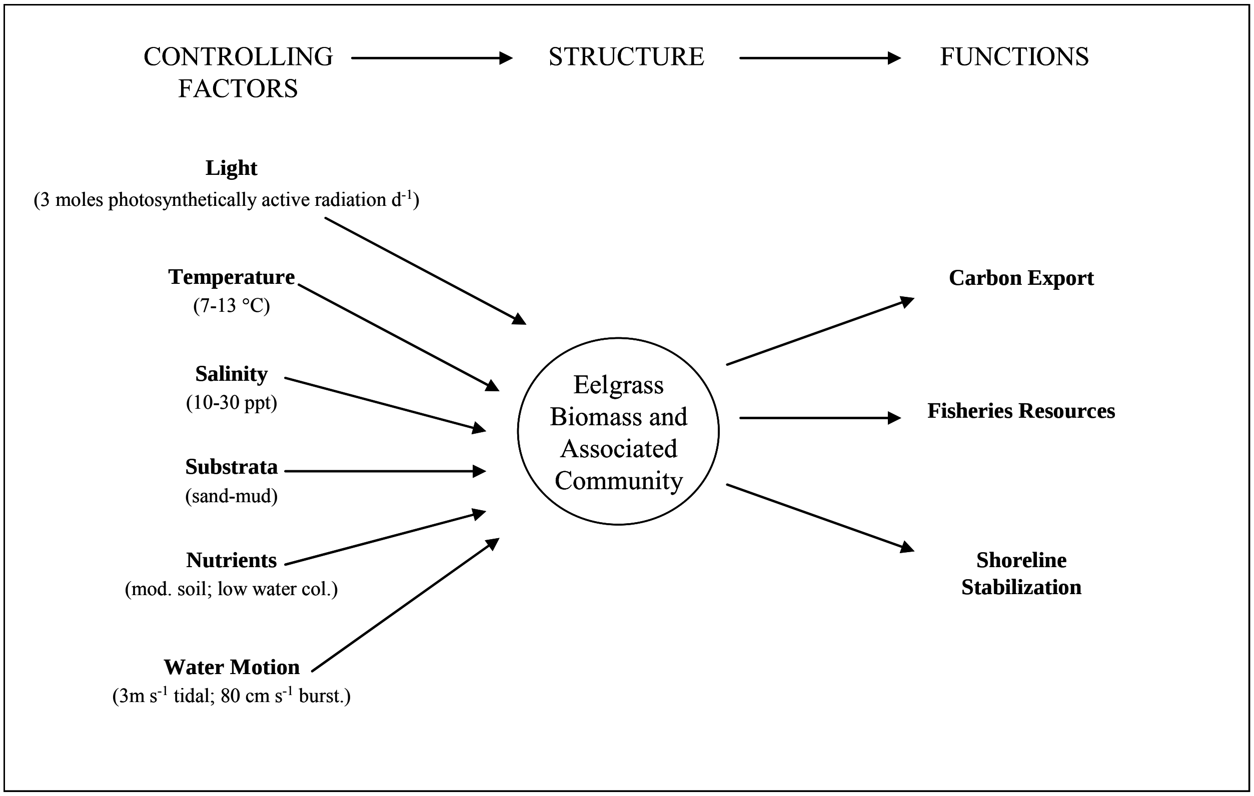

Figure 1. An example of a simple habitat-based conceptual model for eelgrass

For habitat structure, list the dominant species or community type and the parameters that are appropriate for measuring the structure of the species or community type. For example, percentage of cover or shoot density may be the best (and simplest) indicators of the eelgrass meadow structure and development. Finally, if the goal for the project is a process (e.g., primary production) or function (e.g., prey resources for salmon), list those metrics.

Restoration-based model. This model format provides a summary of actions that can result in restoration of a particular habitat through restoration of the processes that control the formation and maintenance of the habitat (Figure 2). It also links to functional responses. This model can be project-specific in terms of the stressors acting on the nearshore processes and controlling factors that are presently limiting the development or quality of the habitat at the site. For example, reducing overwater structures and boat disturbances will result in better light penetration and less bottom scouring, which may presently explain the lack of eelgrass at the site. Implementation monitoring may show that boat disturbances have been effectively reduced through signage. Action effectiveness monitoring may show that this has resulted in recovery of sediment conditions and eelgrass.

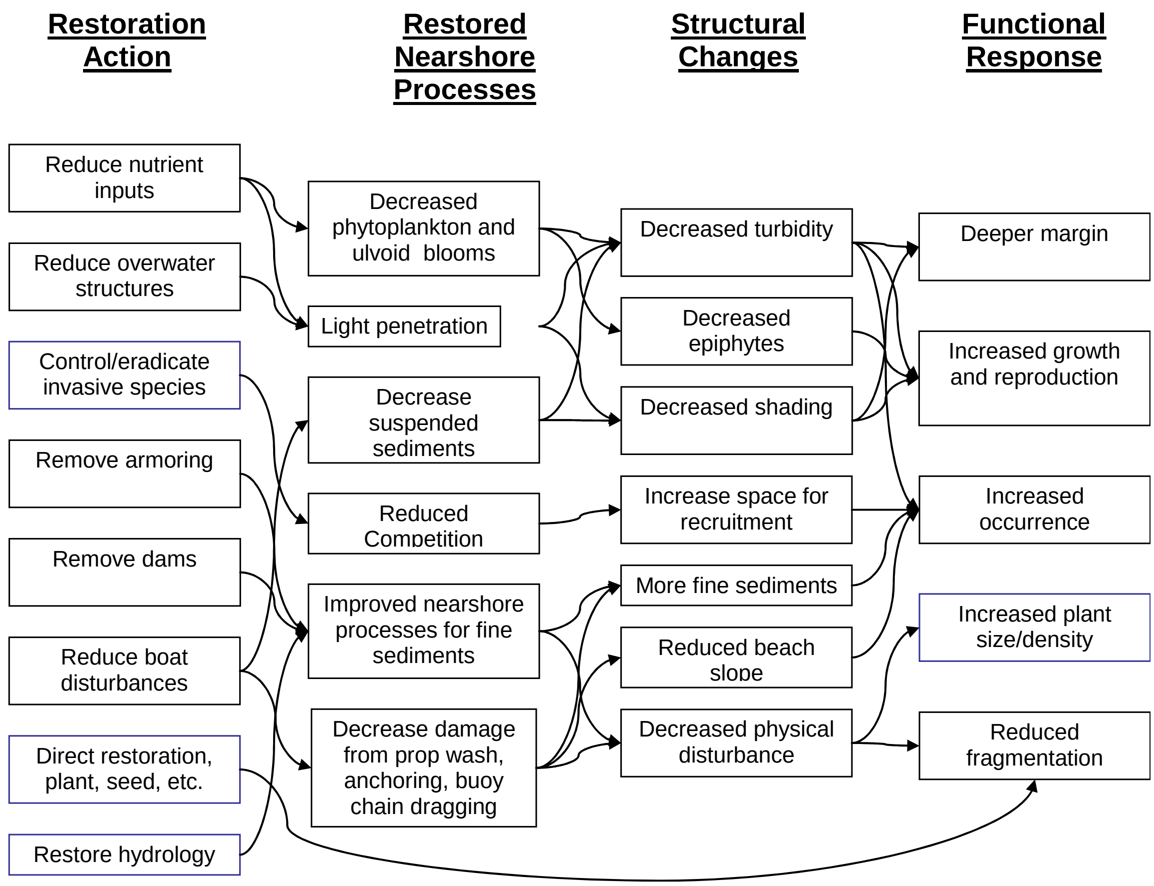

Figure 2. An example of a restoration-based conceptual model for eelgrass (Mumford, 2007).

A practical application of a restoration-based model is provided for the Clinton Ferry Terminal (Figure 3; Thom et al. 2005b). In this project, research was used to indicate the sources of disturbance or stress to eelgrass by ferry terminals and ferry boat operations. Once these were understood, the appropriate avoidance, minimization and compensation actions were developed. Compensation was done by planting eelgrass in plots where eelgrass was expected to survive.

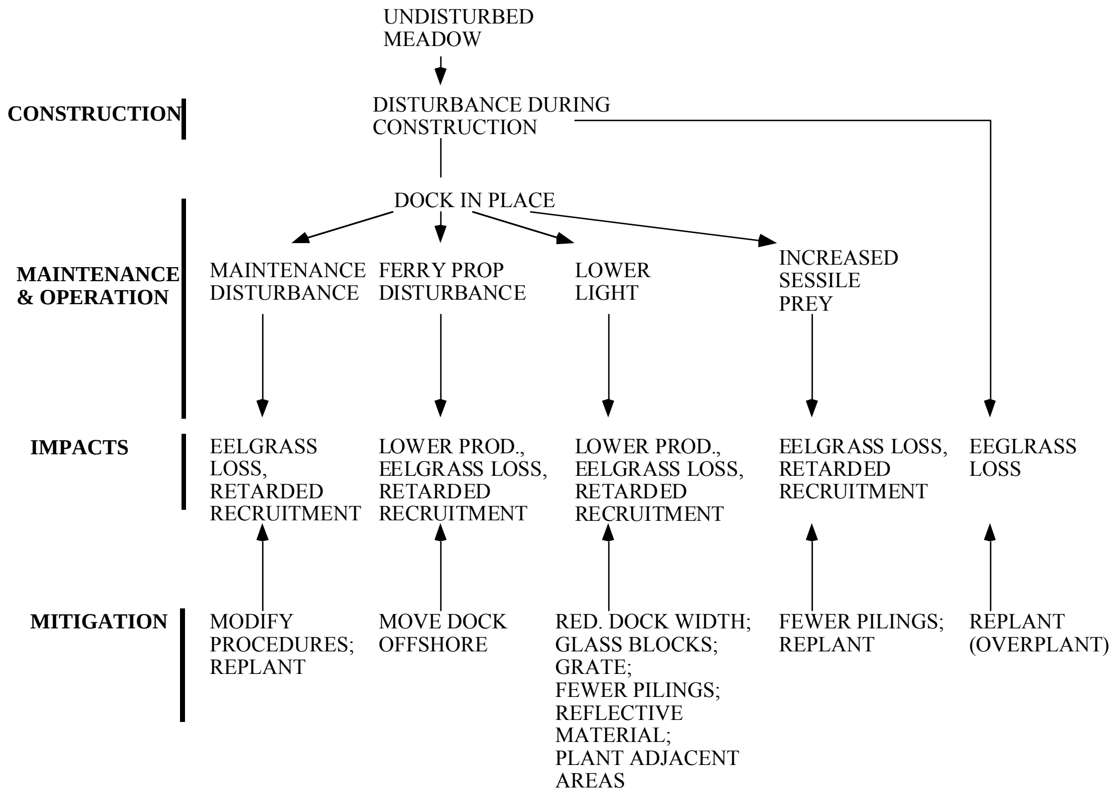

Figure 3. Application of a restoration-based conceptual model to restoring eelgrass near the Clinton Ferry Terminal (from Thom *et al.* 2005b).

Final points about the models are as follows. First, the format of the models does not need to be the same as that in the examples above. However, the more complex a model becomes, the less useful it may be for practical application. Second, if quantitative models relevant to the system and project goals exist, consideration should be given to their use. Third, the models must be based on solid scientific evidence available from the literature. Finally, the models should form the basis for highlighting uncertainties. An important function of the models is to show key relationships that are not well understood and that could be assessed through monitoring.

Step 3. *Choose performance criteria and triggers*

Performance criteria. Performance criteria are standards by which to assess measurable or observable aspects of the restored system and thus to indicate the progress of the system toward meeting its goal. The linkage between goal of the project and the performance of the system is critical, and depends upon clearly defining the performance criteria relative to the goal. Continuing with the eelgrass example, if the goal were to restore a functioning eelgrass meadow at a site, performance criteria might be the presence of eelgrass cover over 60% of the site, persistence of the eelgrass on the site over several years, and presence of eelgrass-associated fauna (e.g., bay pipefish, black brant). These criteria directly measure whether eelgrass can exist at the site, whether it is self-maintaining, and whether it is resilient to disturbances and climate variation over time, and of adequate quality to attract commonly associated fauna. The bay pipefish and brant are attracted for uses such as refuge and feeding; therefore, they are *realizing* (*sensu* Simenstad and Cordell 2000) the function of the eelgrass meadow. Simenstad *et al.* (1991) provided a useful set of habitat attributes that are an excellent basis for selecting criteria and parameters.

Triggers. The performance criteria should have a time-line based on the best available science. For example, studies have shown that eelgrass can take 3-6 years or longer to fully develop in restored areas (Thom *et al.* 2005b). If the performance is not being met after the specified time, this should *trigger* a response by the project managers. Interim trigger points are also advised, especially where uncertainties are substantial. For example, we might propose that eelgrass will develop and meet criteria within 6 years following planting. However, if after one year 90% of the eelgrass has disappeared, this should trigger a response. The triggers and response alternatives are aspects of the adaptive management plan discussed below.

Hypotheses. Performance criteria and triggers essentially form hypotheses that are tested during the monitoring program. The general null hypothesis might be – H_0*: the planted meadow shoot density is the same as the reference meadow density within five years*. If the null hypothesis is found not to be true, then the practitioner needs to assess why. To help explain why, the monitoring program should be set up to provide information on factors that likely would contribute to rejecting the null hypothesis. Furthermore, the alternative actions should the null hypothesis not be met, should be specified in the planning phase. As an applied example, the performance criterion, stated as a null hypothesis, for the Clinton project was – H_0*: the planted meadow shoot density is at least 85% of the reference meadow density within five years*.

Step 4. *Choose monitoring parameters and methods*

Selection of parameters. The conceptual model provides a simple tool for identifying and justifying key parameters to monitor. Specifically, the performance criteria, which are based on the conceptual model, should specify parameters that should be measured. In addition, in planning the project, the identification of key uncertainties that might affect the ability of the site to meet project criteria provides another potential set of parameters. Monitoring a wide array of parameters is costly and is generally not required. Monitoring a few parameters of critical importance can be accomplished efficiently, and can provide information critical to assessing the site, addressing uncertainties and determining responses.

In the eelgrass example, the goal would be effectively assessed by measuring percentage cover, along with the presence of bay pipefish and black brant. However, as an example, if during the site assessment studies, it were determined that disturbance by wakes from passing boats might cause sufficient disturbance to affect plant distribution and survival, and perhaps, habitat use by brant, it could indicate that additional parameters should be monitored. We know from the conceptual model that light is critical to eelgrass growth. Therefore, if the wake disturbance observed were related to resuspension of fine sediment, which consequently would reduce water clarity, it could be important to monitor light at the eelgrass site. Further, in such a case, monitoring light during periods of high and low boat traffic could be advisable.

The NRC (1992) recommended that for aquatic restoration sites, at least three parameters be selected, and that they include physical, hydrological, and ecological measures. In the eelgrass example, light would represent the critical physical parameter; depth range over which the meadow is planned would represent the hydrological parameter; and eelgrass cover, bay pipefish and brant presence would be the ecological measures. In the terminology of the conceptual model, depth and light are controlling factors, eelgrass cover is the habitat structure, and fish and bird presence are functions. Obviously, the sampling of these parameters will differ in time and space. For projects with higher sources of uncertainty, a larger set of parameters may be required to better manage the project toward its goals.

For the Clinton ferry terminal eelgrass project, eelgrass shoot density and plot area were the primary parameters monitored to assess the progress of the project toward its performance criterion (Thom *et al*. 2005b). In addition, the abundance and taxa composition of epibenthic zooplankton were sampled in spring as a measure of the function of the meadow as habitat for feeding by juvenile salmon. Depth, sediment disturbances, wood debris, and floating ulvoids were assessed because it was suspected that these factors could affect the density and development of eelgrass.

Study Design. In simple terms, the restoration project is an experiment with a null hypothesis that the restored site will be no different from a natural site within a certain period of time. The alternative hypothesis is that the restored site differs from a natural site. In order to test this hypothesis, sampling of performance parameters should be carried out in a statistically valid manner. There are volumes written on study design, and it is recommended that the manager consult with individuals knowledgeable in design and relevant published references.

Typically, the design calls for sampling in an unbiased manner with enough replicate samples to provide acceptable power in evaluating the null hypothesis. It is recommended that highly complex designs and analyses be avoided where possible. Often a simple comparison of bar charts with error bars (e.g., 80% confidence limits) is all that is required for the manager and others to assess with confidence whether or not the site is meeting the goals. The natural site is the *reference site* with which the restored site is compared. However, it is challenging to find ideal reference sites. If possible, a suite of reference sites from the region should be used to find a *range* of values of the selected parameters typical for the region. Figure 4 shows several reference sites compared with a planted eelgrass site in Grays Harbor, Washington (Thom *et al.* 2001). If the restored site parameter values (e.g., eelgrass cover) fall within the range of reference site values, it indicates that the restored site is performing as might be expected for that region. A region in this case is defined as a local area with relatively homogenous physical and chemical conditions important to the type of habitat being restored.

The design for the Clinton Ferry terminal project involved restoration plots barren of eelgrass and paired reference plots immediately adjacent to the restoration plots. Shoot density and cover were assessed in triplicate quadrat samples arranged at points within each plot in using a systematic placement from a random starting point. One sample point was allocated per $8m^2$ area of each plot. For example, a $50m^2$ plot would be allocated six sample points.

Sampling Methods. It is important to use methods that have been proven to have scientific validity. Sampling methods and protocols exist for Puget Sound nearshore habitats (Simenstad *et al*. 1991) as well as for a similar suite of habitats in the Columbia River estuary (Roegner *et al*. 2006). These methods are useful staring points for designing the monitoring program. The methods may need slight modification, depending on the situation. Obviously, different methods should be used depending on the goals and criteria of the project.

Timing, Frequency, Duration. Field sampling should be conducted during the time of year as dictated by the performance criteria and monitoring parameters. For example, eelgrass cover might best be sampled during summer when cover is greatest. Supplemental off-season qualitative observations are also useful

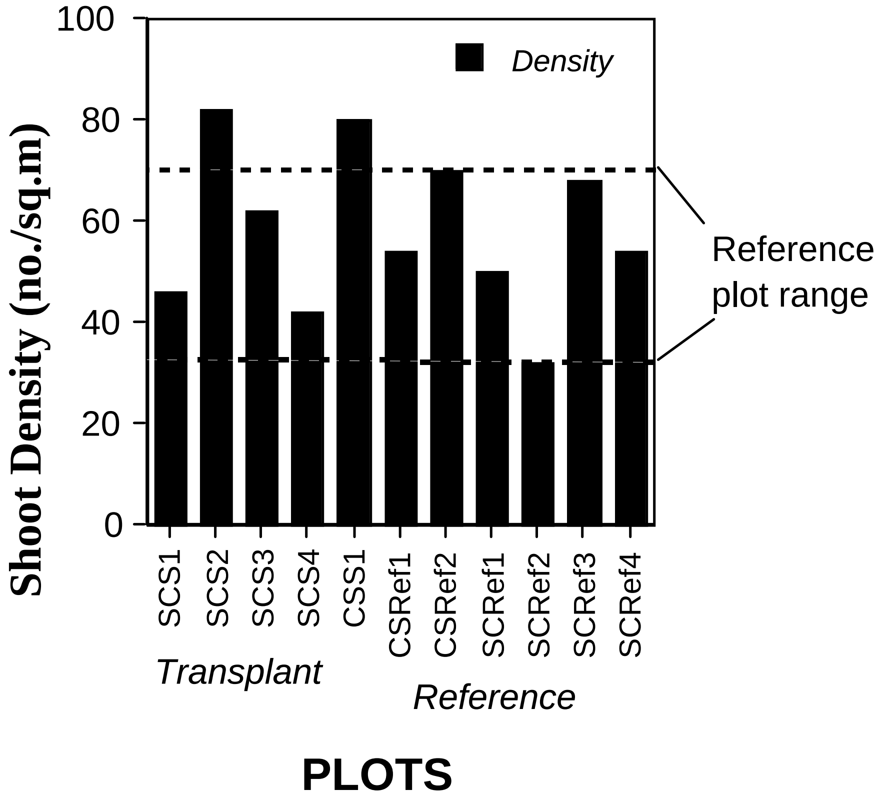

Figure 4. Example of eelgrass shoot density in transplant plots compared with the range of densities in nearby reference plots (these data are from plots in Grays Harbor estuary, Thom *et al.* 2001).

to detect impacts of disturbances, such as storms in winter. Bracketing the sampling can help reduce variability estimates between years. For example, because weather varies year to year, the point in summer of peak cover of eelgrass may vary. Hence sampling in June, July and August and averaging these values may help produce a stronger estimate of summer eelgrass cover. Observations of brant presence should be made in autumn-winter for these examples, when brant are most abundant in the Pacific Northwest

Frequency of sampling refers to the period of time between sampling events. Newly restored sites generally develop most rapidly over periods of 1-6 years. Problems in development are more likely to occur during this early stage; therefore, more frequent sampling during this period could provide the manager with information that could help make midcourse corrections. Frequency is dictated by the nature of the parameter. Annual measurement of eelgrass cover may be adequate, for example, whereas automatic recording by minute, using a sensor and data recorder during the spring and summer, may be more suitable for light. Spring and summer light tends to be most critical to eelgrass persistence over the long-term (Thom *et al*. in preparation)

Duration of sampling depends largely on the type of system and the expected rate of development. The latest scientific literature indicates that most estuarine habitat types require at least 5 years of monitoring to track the *trajectory of development* and to be relatively sure that goals will be met (e.g., Simenstad and Thom 1996) More frequently, sites are being monitored for 10 or more years (e.g., Thom *et. al.* 2002). In cases of some habitat types, such as tidal forested swamps or subsided tidal marshes, which may require decades to develop, a protracted monitoring program with long frequency is needed. However, early monitoring can be used to verify that the system is proceeding toward its goal. This is a new area of research in restoration of tidal systems.

At the Clinton Ferry terminal, eelgrass is sampled qualitatively in fall, winter and spring, and quantitatively in summer. The qualitative samplings involve observations made by divers over the restoration and reference plots. These qualitative observations serve to identify natural (e.g. crab burrowing; storm wave damage) and human-caused (e.g., barge grounding) disturbances that may affect the survival of eelgrass. Quantitative sampling is done in summer during the period of peak biomass and shoot density. Each restoration plot will be sampled annually for 10 years following planting.

Imagery. Photographs from permanent photo points, vertical close-up photographs of plots, video imagery of transects, aerial imagery, and remote satellite imagery are often useful in documenting qualitative aspects of project development. They can also provide quantitative information, if appropriate image processing methods are used. At the least, images collected in a systematic manner over time can offer project staff visual reminders of the site conditions and can help them to effectively portray the conditions to others. If established as a monitoring parameter, photo imagery can provide data for evaluating performance criteria.

Step 5. *Characterize the types of data, data quality, and management plan.*

Monitoring data. Experts on data management and quality assurance should be consulted in all but the simplest of projects. Some basic points for data collection and storage are as follows:

- Develop a list of the types of data to be gathered, and make standard forms to record the data to help ensure complete field collection of all required information.
- Train each field staff member who conducts the sampling to understand the types of data to be collected, the methods for recording data and for recording anomalies in sample procedures, and the type of supplemental notes to record that could help in later analysis.
- Store data in a systematic and logical manner, accompanied by a description that can be clearly understood by someone not involved in the project. Data and methods should be repeatable by others not originally involved in the design or initial sampling of the project.
- Organize the data electronically in a manner that is readily analyzed statistically, and that is suitable for the generation of graphics.
- Check for quality assurance; the review should be conducted by an independent person knowledgeable about the types of data sets gathered.
- Store copies of the field and electronic data in separate locations.

Supplemental Information. Assessment of the results of the project can benefit from additional information gathered by others. For example, the National Weather Service reports data that may help sort out anomalous weather conditions that could affect project performance. Other useful data sets include river flow, storm events, hatchery releases, solar irradiance, ocean climate conditions (e.g., El Nino), etc. Communication with others conducting projects of a similar nature in the region can identify any trends in performance that are linked to regional conditions. The project manager should consider sources of supplementary data that might be available without cost and that could be useful interpreting project results. For eelgrass, the monitoring program in Puget Sound provides a powerful set of information on temporal and spatial variables in eelgrass in the region (Dowty *et. al.* 2005).

Step 6. *Determine level of effort, roles, and cost.*

In Step 6, the project manager must define the task assignments and schedule for the monitoring program designed in Step 4 and distribute it to all involved. If more than one agency, firm, or individual is involved, it is important to define roles and to develop commitments. If funding is to be requested, the study design and mix of participants should be used to develop the costing. The primary categories for costing include labor, rental or purchase of equipment, travel, and subcontracts. Labor should include time for planning, data management, analysis, presentation, reporting and other management needs. As a general rule, most studies with a field component require more time for data management, analysis, reporting, contract management, client communication, etc., than for the actual field work.

Step 7. *Conduct analysis, assess alternatives, report results.*

The results of the monitoring program are critical to management of the project toward its goal. Monitoring provides the basic information both to verify attainment of the goal and to assess alternatives that may need to be implemented to adjust the project to better meet the goal. In Step 7, the performance criteria and triggers identified in Step 3 are evaluated with respect to the data from the monitoring program. If the triggers are invoked, then one option in a set of alternative actions should be implemented. However, it is critical to involve the stakeholders in the final assessment of actions. The three basic actions if the project is not meeting its goals and is invoking triggers are as follows:

> ***No action*** – this is appropriate if the project is progressing as expected or if progress is slower than expected but the information indicates that the project should reach its goals within a reasonable amount of time. This "do nothing" action means that the project needs more time. Anomalous climate conditions or a one-time disturbance event can affect projects; when conditions return to normal, development should proceed as expected.
>
> ***Maintenance/enhancement*** – this "do something" action means that some sort of physical change or biological effort is required to adjust the performance of the project toward its goal. For example, water depth for eelgrass plantings may have been uncertain. If monitoring showed that most plants on the upper elevations of a planted plot died, but those near the lower end were flourishing, then expansion of the eelgrass over its full range of depths might require planting at greater depths.
>
> ***Modification of project goal*** – Under adaptive management, the project goal can be modified. Changing the goal can require a change in the performance criteria and triggers. A goal can be

changed if after a reasonable effort there is no chance of its successful attainment. That means, for example, that the goal was unrealistic for the site and level of effort, that it did not accurately reflect the stakeholders' original vision for the project, that new scientific information was discovered that suggested that a goal change was prudent, or that social decisions were made that affected the original goal. It is imperative that the decision to change the goal (or performance criteria or triggers) be based on science and on full discussions with stakeholders.

For example, if eelgrass shoot density were ~30% of the performance criterion that required eelgrass density to be similar to that of reference sites within 3 years, the low density would trigger a need for an action. However, in our example, monitoring showed that the reference sites, although near the planted site, existed in sediments that were finer and somewhat more organically enriched than that of the planted plot. Supplemental information from regional studies showed that eelgrass densities in coarser substrata generally contained lower shoot densities. Hence, in comparison with similar substrata, the planted plot was within expected shoot density levels. In this case, the goal would not be changed (e.g., restoring an eelgrass meadow), but the performance criterion and trigger could be lowered.

Broader use of monitoring information. The experience of the project team during monitoring is valuable in improving restoration. Monitoring data can be used to inform the project managers as well as those running a program under which the project is implemented. In addition, the results can benefit projects within other programs. To advance the science and technology of restoration, information must be shared. Project reports, presentations, workshops, and information posted on the Internet can be effective vehicles for distributing information to a broader audience. Project reports are the most common mode of information dissemination. Reports and other material should above all be clearly written and succinct. If annual reports are required, they are most efficiently produced using a common format in which sections, tables, and figures are revised annually to incorporate new information. **At the very least, the report should clearly indicate how well the performance criteria are being met, whether triggers were invoked, the adjustments that were made (if any), and the justification for any adjustments.** The monitoring protocols can be adjusted to improve performance measurement. Replication, sample type and size, distribution of samples, etc., should be reviewed annually, and adjustments should be made as needed to produce better data. These topics could be the key sections of the report.

Suggested sections for the report are as follows:

Title – Use a descriptive title, including the monitoring year. For example, "Eelgrass restoration at Half Moon Spit, Washington: Year 3 monitoring and adaptive management report"

Summary – Write a maximum one-page summary highlighting performance relative to the goal of the project and key decisions.

Purpose of project – state the overall purpose of the project and any additional information on project context, the kinds of stressors addressed, any uncertainties that are under evaluation, etc.

Project goal – state the goal in one sentence.

Conceptual model – provide the conceptual model diagram with explanation.

Performance criteria and triggers – present the performance criteria with triggers in a simple table, if possible.

Decision framework with alternative actions – present a table with the three main alternatives (i.e., no action, management/enhancement, modification of project goal) with as much specific detail as possible.

Monitoring results – present succinctly the monitoring results relative to the performance criteria, possibly using tables and figures. Include any statistical tests that were run, with a statement of the hypotheses that were evaluated.

Changes to the project – Using the decision framework, present any changes that were made, and their justification.

Lessons learned – summarize the lessons learned by the monitoring project that may affect the project, the program, or projects within other programs.

Next steps – define the actions and schedule for the next monitoring/assessment period.

Step 8. Make adjustments at project and program scales.

Project-scale adjustments. Projects can benefit from minor and major adjustments to enhance performance. Feasibility of making adjustments versus the benefit realized must be considered. It is advisable to vet the suggested adjustments at the annual meeting of the stakeholders, and invite attendance by experts who may have knowledge of the system and of adjustments that are suggested by the project leader. Some examples of adjustments that have been made in the past are listed here (Borde *et al.* 2007):

- Increasing the size of dike or levee breach to hasten sedimentation and tidal exchange to a tidal marsh
- Placement of floating barriers to block large floating debris from entering the restored site
- Placement of fill or excavation of sediments to enhance elevations to correct levels to support tidal marsh vegetation
- Employing stronger herbicide treatments to eradicate of non-native invasive plant species
- Enhancing nutrients in soils through fertilizer applications
- Using better anchoring stakes to minimize crab disturbances of eelgrass.

The goal for a project can be adjusted also. In practice this often means that the performance criteria are changed. The performance criterion for the Clinton Ferry Terminal eelgrass project was changed after information over a five year period showed that there was high variability in reference site plan densities, and that reference plots and transplant plots differed slightly in depth (Thom et al. 2005b). Both factors made evaluation of the performance criterion of transplant plots having a shoot density of 85% of the reference plots problematic. However, it was noted that because of the high transplant plot area to impacted area ratio (9:1) that 2-3 times more eelgrass shoots within the transplant plots that were destroyed by the terminal construction project. Hence, the *intention* of the restoration goal of no net loss was met if not exceeded. Agency representatives, who had been actively engaged in annual adaptive management meetings on the project, accepted a revised performance criterion of no net loss of total eelgrass shoot abundance as the revised performance criterion. This decision acknowledged the role of natural processes in determining where eelgrass will ultimately flourish. Further, the monitoring program provided critical information on the small-scale processes that drove changes in eelgrass abundance at the site.

Experimental considerations. If critical uncertainties were identified in earlier steps and experiments were designed to evaluate these uncertainties, then the results should be incorporated into the decision process. For example, if the project were to restore eelgrass to a bay where eelgrass had been totally eliminated over a short period of time, and where there are no clear explanations thereof, then experiments should be conducted to determine whether planting would be warranted. In this case, small experimental plantings across the elevation range and in an area where eelgrass once existed would suffice to indicate present site suitability for eelgrass establishment. This experiment should be conducted in conjunction with monitoring of parameters, such as light and temperature, identified by knowledgeable individuals as potentially critical to plant survival and spread. If plants survived over 1-2 years and appeared to spread, and water properties appeared to remain within tolerance limits (using the conceptual model), then full planting would be advised. The assumption is that in the unidentified cause of the loss of eelgrass was episodic in nature. Continued monitoring of the spread of eelgrass, as well as of critical water property factors would be advised to fully evaluate the assumption.

Program-scale adjustments. The information gained through the projects should be passed on to the program that supports the projects. Information that will ultimately result in greater success of projects is highly valuable to future projects. The two primary avenues for communicating learning is through participation by program staff in the annual project meetings where information is exchanged, and through written reports. A visit to the site is also often very informative, and a place where practitioners from several projects can discuss collaboratively what they have learned while pointing out the physical aspects of the site.

Because the focus of this program is the nearshore ecosystem, many projects will be similar in nature. Thus, many of the uncertainties about actions and responses of these actions will be similar. In this case, program managers have the opportunity to develop a program-level experimental approach to projects by setting up projects as replicates in the evaluation of uncertainties. For example, the rate of sediment erosion from a beach that received sediment nourishment as a restoration action can be measured at several beaches that have received similar nourishment. Other programs in the nation have found that in order to obtain the type of data they require for these program-level experiments, it is best to employ a group to collect the data at all of the sites, rather than relying on the project practitioners. Even though protocols may exist, slight variations introduced by multiple investigators can introduce significant variance into the data set.

5.3 Monitoring Framework Summary

Flush out the entire framework <u>before</u> initiating the monitoring program. Seek expert advice and review of the framework to assure it is as efficient and affective as possible. Be clear on the uncertainties up-front, and be clear on actions that are taken initially to evaluate the uncertainties. Be as specific as possible on alternative actions given the set of potential results. Finally, report back what is learned.

The integrated monitoring and adaptive management process is summarized in Figure 5. The outer circle indicates where each step fits into the process, as well as the actions or questions posed at each step. The inner circle shows the program "life cycle" relative to the steps in the monitoring framework. Once developed, the schedule associated with both the project and program can be shown on this diagram.

Finally, the program-level learning is indicated outside the circle. These are the points at which the program managers should capture the project-level information in a systematic way and incorporate the learning into subsequent requests for proposals as well as in the design of experiments that, for example, can be conducted using suites of projects as replicates.

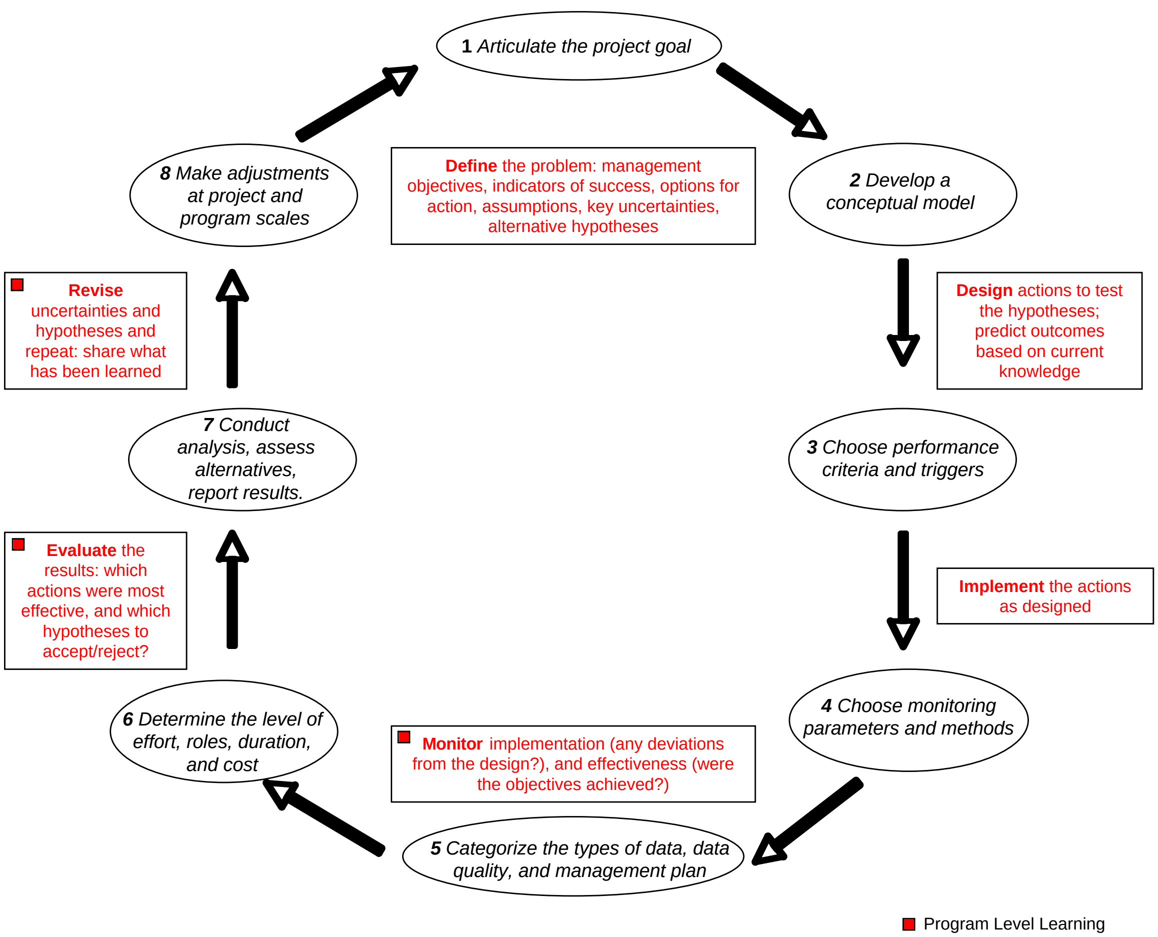

Figure 5. Diagram of the monitoring framework steps relative to the adaptive management cycle.

The integrated monitoring and adaptive management process is also summarized in Figure 6. In addition, this figure indicates how a program-level cycle for reviewing proposals and funding for restoration projects fits within the overall process.

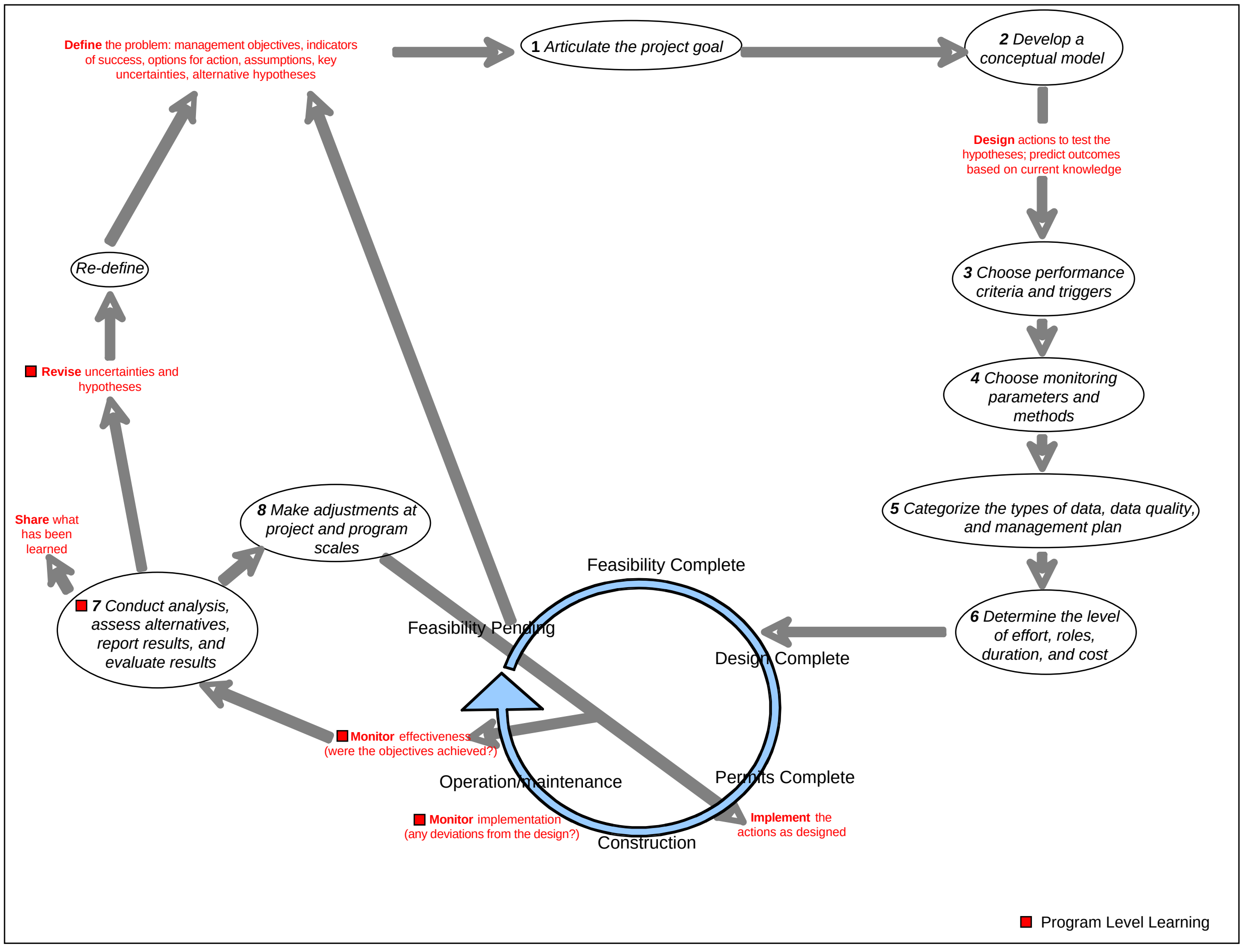

Figure 6. Diagram of the monitoring framework steps relative to the adaptive management cycle as well as a program-level cycle for reviewing proposals and funding restoration projects.

6.0 Acknowledgements

We sincerely thank Washington State Department of Fish and Wildlife and Curtis Tanner for providing us the opportunity to address this important topic. Tom Mumford of Washington State Department of Natural Resources was instrumental in facilitating our work. Charles Simenstad of the University of Washington and chair of the PSNERP science team provided an avenue for scientific review of the document. Paul Cereghino of NOAA kindly gave his advice on the focus of the report. Finally, we sincerely thank project managers for their time and energy to provide information on their projects.

John Vavrinec and Dick Ecker provided internal peer review, Susan Thomas edited and Eileen Stoppani formatted the document.

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8.0 Appendices

Project monitoring plans reviewed as cases studies for this document are included in a separate attachment.