

RPWG  
JJ

**MONITORING RECOVERY FOLLOWING THE *EXXON VALDEZ*  
OIL SPILL: A CONCEPTUAL MONITORING PLAN**

Prepared for

**RESTORATION PLANNING WORK GROUP**

*Exxon Valdez* Oil Spill Group  
645 "G" Street  
Anchorage, Alaska 99501

Prepared by

**PARAMETRIX, INC.**  
5808 Lake Washington Blvd. NE  
Kirkland, Washington 98033

In association with

**ABA Consultants**  
P.O. Box 1151  
Capitola, California 95010

**Goldstream Consulting**  
P.O. Box 83090  
Fairbanks, Alaska 99708

June 25, 1993

## ACKNOWLEDGEMENTS

Parametrix would like to acknowledge the constructive input of its team members on the project, ABA Consultants and Goldstream Consulting. Dr. Rikk Kvitek (ABA) and Mr. Howard Maxwell (Goldstream) provided considerable support, particularly during the workshop phase of the program. Additionally, the whole team would especially like to thank Dr. John Strand, Ms. Karen Klinge and Mr. Chris Swenson, as well as the rest of the Restoration Planning Work Group (RPWG) for their input and support through development of the plan. Thanks are due to those who participated in the interviews and workshop portions of the project, particularly the principal investigators, peer reviewers, Restoration Team members, and again, RPWG members. (A list of participants is provided in the appendices of this plan.) Constructive comments on the plan were received from several peer reviewers, including Donald Boesch, Jeff Hartman, Dennis Heinemann, Jon Isaacs, Phil Mundy and Charles "Pete" Peterson, and Jim Richardson—Thank you. This project (Contract No. 50ABNF300041) was funded by the *Exxon Valdez* Oil Spill Trustee Council with civil settlement funds, overseen by the RPWG, and administered by Dr. John Strand of the National Oceanic and Atmospheric Administration.

## TABLE OF CONTENTS

	Page
EXECUTIVE SUMMARY .....	v
1. INTRODUCTION .....	1
1.1 BACKGROUND .....	1
1.2 WHAT IS A CONCEPTUAL MONITORING PLAN? .....	1
1.3 WHY MONITOR RECOVERY? .....	2
1.4 CONSTRAINTS ON MONITORING .....	3
1.5 MONITORING PLAN APPROACH AND DESIGN .....	4
1.6 PLAN ORGANIZATION AND CONTENT .....	9
2. DEFINITIONS OF RECOVERY AND MONITORING TYPES .....	11
2.1 RECOVERY .....	11
2.2 MONITORING TYPES .....	12
2.2.1 Recovery Monitoring .....	12
2.2.2 Project Monitoring .....	12
2.2.3 Long-term Monitoring .....	13
3. GOALS, OBJECTIVES, AND STRATEGIES .....	14
3.1 GENERAL MONITORING PLAN .....	14
3.2 RECOVERY AND PROJECT MONITORING .....	22
3.3 LONG-TERM MONITORING .....	25
4. CONCEPTUAL METHODOLOGY .....	29
4.1 RESOURCES TO MONITOR .....	29
4.2 SERVICES TO MONITOR .....	30
4.3 MECHANISMS FOR ESTABLISHING MONITORING PRIORITIES .....	31
4.3.1 Involvement of User Groups and Consensus Building .....	31
4.3.2 Development of Goals, Objectives and Strategies .....	32
4.3.3 Recovery Endpoints .....	32
4.3.4 Criteria for Selecting and Evaluating Monitoring Activities .....	37
4.3.5 Linkages Between Resources and Services .....	48
4.3.6 Development of Conceptual Models .....	49
4.3.7 Other Methods for Setting Monitoring Priorities .....	49
5. GUIDANCE ON SAMPLING DESIGN .....	52
5.1 MONITORING PLAN PRINCIPLES .....	52
5.2 PRELIMINARY STUDIES .....	52
5.3 SAMPLING DESIGN .....	52
5.3.1 What to Measure .....	53
5.3.2 Where to Measure .....	54

**TABLE OF CONTENTS**  
(continued)

		<u>Page</u>
	5.3.3	How to Measure . . . . . 54
	5.3.4	When to Measure . . . . . 55
	5.3.5	Data Organization . . . . . 55
	5.3.6	How to Analyze . . . . . 55
	5.3.7	How to Interpret . . . . . 56
5.4		USE OF EXISTING INFORMATION . . . . . 56
5.5		GENERAL GUIDANCE ON SAMPLING RESOURCES . . . . . 57
	5.5.1	Avifauna and Mammals . . . . . 57
	5.5.2	Fisheries . . . . . 58
	5.5.3	Intertidal/subtidal . . . . . 59
	5.5.4	Archeological Resources . . . . . 61
5.6		GENERAL GUIDANCE ON SAMPLING SERVICES . . . . . 62
	5.6.1	Recreation . . . . . 62
	5.6.2	Subsistence . . . . . 64
	5.6.3	Commercial Tourism . . . . . 65
	5.6.4	Commercial Fishing . . . . . 66
	5.6.5	Passive Uses . . . . . 66
6.		RELATIONSHIP TO OTHER MONITORING PROGRAMS . . . . . 68
	6.1	RESOURCE AND SERVICE MONITORING PROGRAMS . . . . . 70
	6.1.1	Alaskan Monitoring Programs . . . . . 70
	6.1.2	Private or Other Programs . . . . . 83
	6.1.3	Future Programs With Which to Coordinate . . . . . 85
	6.1.4	Monitoring Programs to Learn From . . . . . 85
	6.2	SERVICE MONITORING PROGRAMS . . . . . 88
7.		MANAGEMENT OF MONITORING PROGRAM . . . . . 91
	7.1	MANAGEMENT STRATEGY . . . . . 91
	7.1.1	Peer-Review Panel . . . . . 93
	7.1.2	Funding . . . . . 94
	7.1.3	Data Management and Dissemination . . . . . 94
	7.1.4	Avoiding Duplication of Effort . . . . . 95
	7.2	REQUEST FOR PROPOSAL AND CONTRACT LANGUAGE . . . . . 95
	7.2.1	Payment Tied to Deliverables/Schedule . . . . . 96
	7.2.2	Percent Reduction in Contract Total Value . . . . . 97
	7.2.3	Incentive for Continuing Project Involvement . . . . . 97
	7.2.4	Schedule for Deliverables and Performance Criteria . . . . . 97
	7.2.5	Proposal Ranking . . . . . 98

**TABLE OF CONTENTS**  
**(continued)**

	<u>Page</u>
8. RECOMMENDATIONS .....	99
9. REFERENCES .....	102

APPENDICES

- A QUESTIONNAIRES FOR DEVELOPMENT OF PRELIMINARY DRAFT OF CONCEPTUAL PLAN
- B LIST OF INTERVIEW PARTICIPANTS
- C LIST OF WORKSHOP PARTICIPANTS
- D GENERAL GUIDANCE ON SAMPLING AND STATISTICAL ANALYSES

The conceptual monitoring plan presented here establishes a framework for Phase 2 activities. A number of strategies are presented here which are considered critical to the success of Phase 2:

1. Build consensus or *ownership* through user group participation.
2. Follow the strategies outlined herein to meet the monitoring goals and objectives defined.
3. Confirm for each injured resource and service those elements that could be monitored to determine the rate of recovery (termed throughout as *recovery endpoints*).
4. Apply the criteria presented herein to determine monitoring priorities.
5. Evaluate costs in light of the monitoring priorities.
6. Develop conceptual models for each injured resource and service, establishing linkages and interactions among biological, physical and chemical parameters, as well as social, cultural and economic influences.

Consensus building has been used throughout plan development. Its use resulted in agreement on a list of goals, objectives and strategies for monitoring, a synthesis of recovery and monitoring endpoints for the injured resources and services, agreement on the criteria for evaluating monitoring priorities, including which criteria are most important, and agreement that resources and services had to be prioritized, and that the user groups should be involved in program development. Building consensus or ownership into phases 2 and 3 activities is recommended.

The following goals are defined for all three types of monitoring:

- Assure a scientifically and publicly credible program.
- Establish an accessible and/or integrated, well-designed database.
- Collect information for long-term management of injured resources and services.
- Establish a link between project approval and funding.
- Set guidelines for consistent and timely data reporting.
- Disseminate information to the user groups.

Recovery and project monitoring share three additional goals. They must (1) prioritize monitoring activities; (2) document recovery and the rate of recovery; and (3) establish linkages among resources and services.

Long-term monitoring goals must specifically address: (1) the natural and anthropogenic stresses affecting resources and services; (2) temporal and spatial variations in population distributions and abundances (to speed identification and responses to catastrophic events); and

## EXECUTIVE SUMMARY

Monitoring is necessary to determine whether injured resources and services recover from the 1989 *Exxon Valdez* oil spill. The Trustee Council, overseeing the civil settlement funds from the spill, plans to implement recovery monitoring in a three-phased approach, with the first being the development of this conceptual monitoring plan. This plan outlines monitoring goals, objectives and strategies, and describes a conceptual methodology for achieving them.

In this plan *recovery* refers to a return of resources and services to the estimated populations and prevailing conditions had the oil spill not occurred. The Trustee Council identified the injured resources (species, archeological sites and designated wilderness areas) and services (uses of resources such as tourism, fishing, recreation and subsistence) to monitor.

The Trustee Council proposed three types of monitoring—recovery, project, and long-term—to assess: (1) natural and assisted recovery rates of injured resources and services; (2) effectiveness of restoration activities; (3) whether a need exists for additional restoration activities; (4) information gained on the ecosystem—how the different components interact with one another and how they may respond to future perturbations; and (5) injuries beyond those already identified in the Natural Resource Damage Assessment (NRDA).

The three proposed monitoring types are differentiated in the definitions provided below:

- **Recovery Monitoring:** Monitoring of assisted and unassisted recovery of injured resources and services. Recovery monitoring is population level monitoring in that the information gained on a resource or service will be used, whenever possible, to ascertain its recovery throughout the spill area. Recovery monitoring will probably not be able to discern whether recovery is due to natural or assisted means.
- **Project Monitoring:** Monitoring the effectiveness of select restoration activities. Project monitoring may be a subset, or element of recovery monitoring, in that it is monitoring the effect of a specific restoration activity on a select or discrete population or geographic location.
- **Long-Term Monitoring:** Long-term monitoring, or trend monitoring, is defined here as monitoring of the distribution and abundance of resources and the quality and quantity of services over several years to develop a baseline of information to detect changes.

## LIST OF TABLES

<u>Table</u>	<u>Page</u>
1 Matrix of recovery endpoints for injured resources and services . . . . .	33
2 Criteria for evaluating resources and services for monitoring . . . . .	38
3 Workshop example of application of criteria to the injured resources . . . . .	43
4 Example matrix of injured services for application of criteria . . . . .	46
5 Matrix table of linkages between resources and services . . . . .	63
6 Matrix of resources and services, and elements monitored by other programs . . . . .	69

## LIST OF FIGURES

<u>Figure</u>	<u>Page</u>
1 Essential Elements of a Conceptual Monitoring Plan . . . . .	5
2 Framework for Three-phased Approach to Monitoring . . . . .	7
3 Framework for Defining Study Strategy . . . . .	8
4 Criteria Application Process . . . . .	39
5 Three-Dimensional Graph Illustrating Results of Application of Primary Criteria to the Injured Resources . . . . .	44
6 Three-Dimensional Graph Illustrating Results of Application of Primary Criteria to the Injured Bird Species . . . . .	45
7 Example Conceptual Model of Fate and Transport of Oil . . . . .	50



(3) linkages between physical, biological and chemical parameters, as well as social and cultural interactions.

Following through with the strategies developed to address the monitoring goals is an activity that should be ongoing throughout the monitoring process. Periodic review of the program goals provides a feedback mechanism to ensure that the intent of the monitoring program is met.

The recovery endpoints for each resource and service may call for different types of monitoring. For example, recovery endpoints for *biological resources* include factors such as population size, reproduction and growth rate. For *archeological resources* the reduction of looting and determining when concentration of hydrocarbons no longer affect the organic components of the sites are the recovery endpoints. Endpoints for *services* include regaining a certain level of usage, and the achievement of compensatory action in terms of the quantity, quality, location and the public's perception of the action.

Three primary criteria were developed as a mechanism for determining monitoring priorities for resources and services. Application of these three criteria provide an effective initial screening tool. The three monitoring priorities are: severity of injury, ability to monitor, and resource or service importance. The seven secondary criteria developed will allow further refinement of priorities.

Another monitoring tool described in the conceptual monitoring plan is the conceptual model. Conceptual models help define cause-and-effect relationships and aid in development of testable hypotheses. They also assist with understanding the linkages between resources. To develop sampling designs that answer testable questions, conceptual models documenting interactions of each resource and service with biological, physical, chemical, social, and economic factors should be developed and expanded upon as information becomes available. An example conceptual model of the fate and transport of oil is presented for illustrative purposes in this plan. The conceptual models can be used to evaluate monitoring priorities by illustrating: resources and services with overlapping linkages, the potential for analogous responses to disturbances by resources and services, and elements or interactions to be monitored that address more than one resource or service. Conceptual models should be developed for each injured resource and service.

This conceptual plan not only addresses the monitoring elements and strategies discussed above, it includes suggestions/recommendations in the following areas:

- Sampling design (Section 5)
- Monitoring programs with which to coordinate (Section 6)
- Possible management structures for phases 2 and 3 (Section 7)
- Monitoring database structure (Section 7)
- Competitive bid and peer review system (Section 7)
- Methods to ensure timely, quality deliverables (Section 7)

A brief overview of recommendations made in this conceptual monitoring plan follows. Management by a single contractor or team of contractors utilizing an advisory team or monitoring management council (MMC) is recommended. Management should be performed by an entity without political or economic interests in the direction the program takes.

Peer review is a critical component of management, design and implementation of the monitoring program. A rigorous and timely peer review system should be used. Additionally, a system of rotating reviewers will prevent the same reviewers from reviewing the same programs, thus preventing reviewers from becoming over-familiar with a particular project. The review process provides continuous feedback throughout the program to allow for revisions and improvements.

A competitive bid process should be used to secure monitoring work, in order that monitoring be conducted by the most qualified resource and service experts, and to help ensure that high technical quality, timeliness and cost control are elements of every program.

The proposal and contract for monitoring activities can be used as a tool to ensure that quality products are received in a timely fashion, and to ensure that specific information is provided in proposals and contract deliverables. The Request for Proposal (RFP) and contract scope of work should include language that ties payment into deliverables, and states penalty clauses or incentives for continuing project involvement. Guidelines should be provided with the RFP to ensure respondents are aware of quality assurance/quality control requirements, their responsibility for dissemination of the findings and reporting formats, and study requirements (such as testable hypotheses, development of conceptual models, identification of stresses to the resource or service, and identification of programs they plan to coordinate with).

A database or data library designed to address the needs of the user groups, should be centrally located and accessible by the users. A single individual or organization should have oversight of the database. The data should have common links such as resource and geographic area, and be set up so that it is flexible for additions and changes.

Funding, through establishment of an endowment, should be secured for the life of the monitoring program. Cost estimates for program elements should be used to plan for the overall monitoring budget. Multiple-year contracts should be awarded to ensure that programs are funded for the period during which they are designed to document recovery, rather than intermittent funding or a yearly renewal.

Results of the monitoring should be disseminated and accessible to the users. The format (i.e., forums, periodic summaries or status reports, scientific publications, and electronic submittal) should be specified up front in the RFP and contract, as should publication rights.

Development of Phase 2 and monitoring implementation in Phase 3 depend, in part, on which of the five restoration alternatives is selected from those presented in the *Exxon Valdez Oil*

*Spill Draft Restoration Plan Summary of Alternatives for Public Comment (Exxon Valdez Oil Spill Restoration Office 1993).* The scope of the monitoring and restoration research varies with each restoration alternative because the allocation of funds differs for each alternative. The alternative selected will influence how the conceptual methodology presented in this plan is implemented in phases 2 and 3.

## 1. INTRODUCTION

### 1.1 BACKGROUND

The *Exxon Valdez* Oil Spill Trustee Council (Trustee Council) is developing a Restoration Plan for spill-injured resources and services. One Restoration Plan option is to implement a comprehensive program to monitor recovery. This monitoring program would include the following element:

- Assess the adequacy or effectiveness of both natural and assisted recovery (*recovery monitoring*)
- Evaluate the effectiveness of specific restoration activities (*project monitoring*)
- Document long-term trends in the condition of resources and services affected by the oil spill (*long-term monitoring*)
- Contribute to existing physical, chemical, and biological baseline data on resources and services in the spill area (all types of monitoring)

The monitoring option has three phases. This document addresses Phase 1, the development of a conceptual monitoring plan. The purpose of the conceptual monitoring plan is to provide a framework for the more detailed technical planning during Phase 2, followed by the actual implementation of monitoring in Phase 3.

The Phase 1 plan will help the Trustee Council make decisions about the selection and implementation of monitoring activities. It recommends mechanisms for prioritizing monitoring activities, sets goals and objectives for monitoring, outlines the strategies for meeting the goals, identifies linkages between monitoring components, and identifies existing monitoring programs with which to coordinate efforts. During Phase 2, the framework will be expanded and refined to include resource- and/or service-specific programs and methodologies, including development and review of conceptual models, sampling designs and statistical approaches.

### 1.2 WHAT IS A CONCEPTUAL MONITORING PLAN?

A conceptual monitoring plan is an instrument, identified by the National Research Council (NRC) (1990) in *Managing Troubled Waters*, used to logically direct our nation's environmental monitoring. A conceptual monitoring plan is a guide to decision making about monitoring activities and provides the criteria and procedures desirable for implementing specific monitoring plans.

Its goal is to guide planning and decision-making to produce useful information that can be communicated clearly to the various interest groups.

The NRC describes a conceptual monitoring plan as:

- A tool for developing and refining monitoring approaches
- A means for identifying elements for an optimum monitoring plan
- A guide for making decisions on what, when, how, and where to monitor

### 1.3 WHY MONITOR RECOVERY?

Monitoring is the key to determining whether recovery has occurred. Further, the recovery rate of resources and services can be established through monitoring. The resulting data can, in turn, provide insights about those resources and services that may need assistance to recover.

However, recovery of resources and services is not only a function of whether or not they have reached a defined endpoint. Recovery is also a function of the public's perception and use of those resources and services. Likewise, management of resources and services is largely influenced by the public's perception of recovery. Recovery monitoring provides technical information that the public can use in forming conclusions about recovery.

Monitoring also provides credibility to the Trustee Council's decisions about recovery. The general public, special interest groups (e.g., subsistence, commercial fisherman), and agency technical staff cannot be expected to support decisions of the Trustee Council in the absence of data documenting the status of resources and services.

Monitoring recovery would allow the Trustees to:

- Measure the success and recovery rate of resources and services.
- Determine the effectiveness of selected restoration projects.
- Facilitate resource and service restoration.
- Establish a starting point for future comparisons and improve on existing baseline information to aid in detection of, and response to, effects of future oil spills or other perturbations.
- Serve as a long-term damage assessment.
- Provide a vehicle that may allow detection of previously undocumented injuries to resources and services resulting from the spill.

Monitoring results can be used for various purposes. Results of recovery monitoring may be used to assist in determining how oil and gas development or tanker traffic should be managed. Results may provide information on the effectiveness of spill response activities such as in the comparison of recovery in cleaned versus untreated (oiled) areas. They may also aid in understanding and evaluating population dynamics (i.e., which life stages or age classes are most vulnerable to perturbations, inter- and intraspecies interactions, and recruitment or replacement of species within an ecosystem).

#### 1.4 CONSTRAINTS ON MONITORING

One overriding constraint on monitoring is money. Funds are limited, and to monitor each of the injured resources and services throughout the entire geographic area of the spill—and throughout several generations of the species—would be cost prohibitive. The fact that funds are limited requires that choices be made on what, where, how and when to monitor. Monitoring priorities must be based first on scientific merit, and second, on cost. It is not the intent of this plan that resource-specific monitoring programs be modified to reflect cost constraints, at least not at the jeopardy of scientific rigor. Rather, monitoring activities that have been reviewed for scientific rigor should then be reviewed in light of their costs. Biostatisticians should be included in the review of monitoring elements since the sampling design or sampling frequency may over- or under-addresses the hypotheses being tested, and could seriously affect the cost.

Other constraints on monitoring include lack of baseline information, and logistical, physical, and technical constraints. The lack of baseline information can, in some cases, limit the ability to estimate variation and make statistical comparisons. In some cases, control sites can be used in place of, or in addition to, pre-spill information. Practical considerations may preclude monitoring of some resources or services at particular sites and during particular times of the year.

Logistical constraints (such as weather, tides, extensive geographic area, or remoteness of some areas), can put limits on the information gathered during a monitoring program. The large geographic area affected by the spill presents a technical challenge, especially for long-term monitoring. As such, the sampling design that uses a paired design (such as treatment and control), or before (baseline) and after spill information, may not be practical for assessing future perturbations.

Additionally, information gaps can result in constraints on monitoring. Information gaps might include resources whose life cycles are not fully understood, or whose populations were declining prior to the spill. Other constraints might include resources whose habits are secretive or whose habitat is difficult to work in (e.g., underwater). Thus, even if recovery endpoints are identified for a particular resource or service, they may not be quantifiable, or the resource or service may be too difficult to monitor.

Lack of knowledge on the natural and anthropogenic stresses on the ecosystem and select resources and services is also a constraint. Understanding the monitoring results can be limited if stresses such as winterkill, El Niño, ice scouring, or overharvesting are not considered.

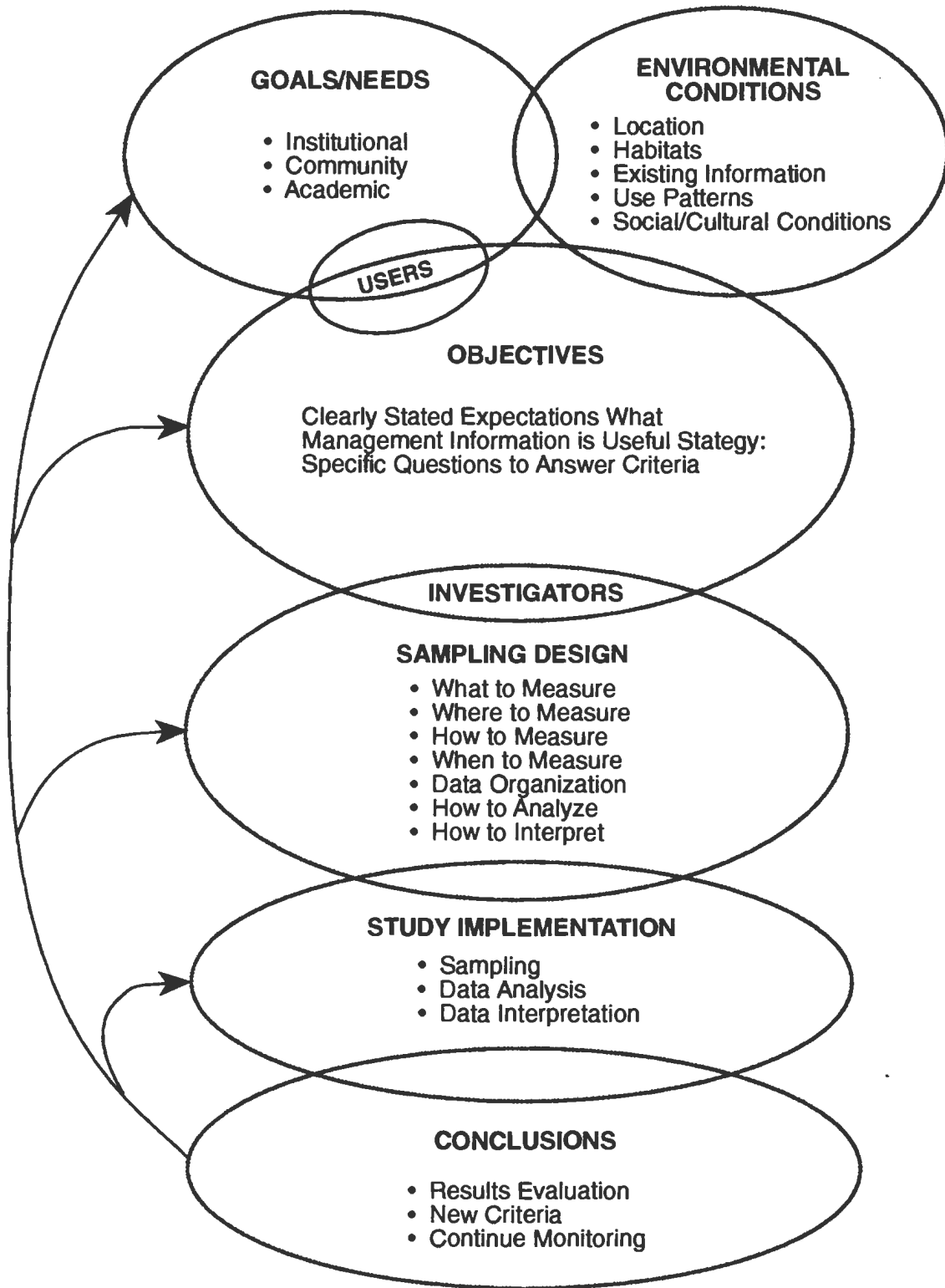
Furthermore, a particular monitoring or restoration activity may have a negative effect on resources and services. This concern is relevant for elements within this program, as well as activities in other unrelated programs. This highlights the need for coordination in the spill area.

In designing and implementing the monitoring program, awareness of these constraints is essential. The monitoring constraints do not override the value gained from monitoring—monitoring is the only tool that will allow the Trustee Council to document recovery of the injured resources and services.

## **1.5 MONITORING PLAN APPROACH AND DESIGN**

A number of elements are essential to a conceptual monitoring plan, as identified by the NRC (1990) (Figure 1). These elements are listed and defined below:

Goals:	A conceptual monitoring plan must take its direction from the goals of the users of the information.
Users:	Those who require monitoring information for management or use of natural resources.
Environmental Conditions:	Knowledge of the existing basic features of the environment, resources, and services (e.g., findings from the Natural Resource Damage Assessment [NRDA], restoration studies, pre-spill information and scientific literature).
Objectives:	Clear statements about what users expect of the monitoring program.
Investigators:	Those who will develop and implement specific monitoring plans, analyze results, and communicate monitoring information.
Sampling Design:	Technical approach to test the hypotheses; what, where, how, and when to monitor; and how data will be analyzed.
Implementation:	Strategy for establishing and maintaining monitoring activities and communicating information.
Evaluation:	Use of the results and conclusions as a feedback mechanism to assess whether monitoring has been effective at documenting recovery, and whether or not monitoring should be continued.



**Figure 1.**  
**Essential Elements of a**  
**Conceptual Monitoring Plan**

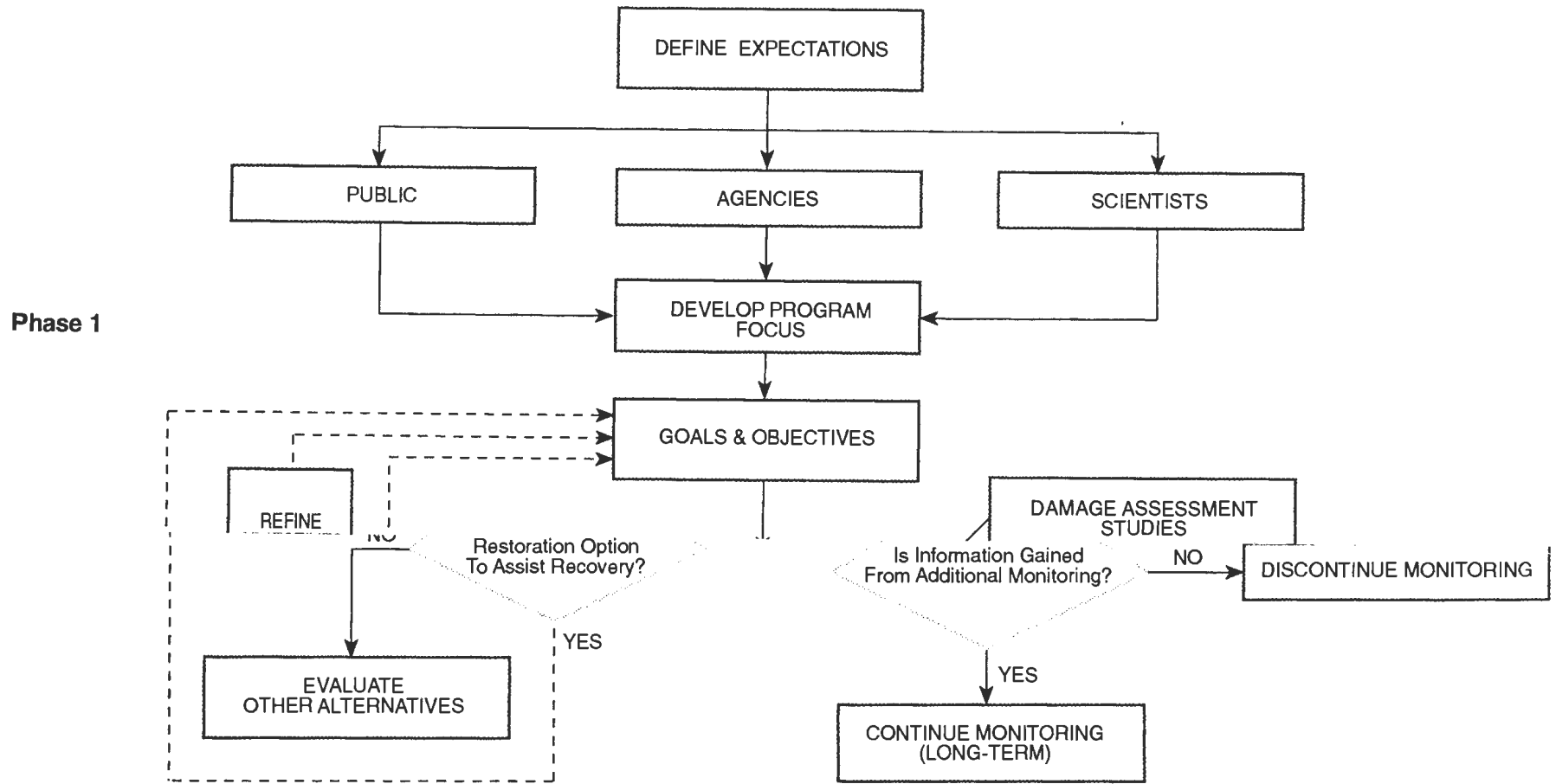


Figure 2 shows how these elements flow from the development of goals and objectives (Phase 1) through monitoring implementation (Phase 3). The *study strategy* element of this figure is further defined in Figure 3 with the development of conceptual models and testable hypotheses.

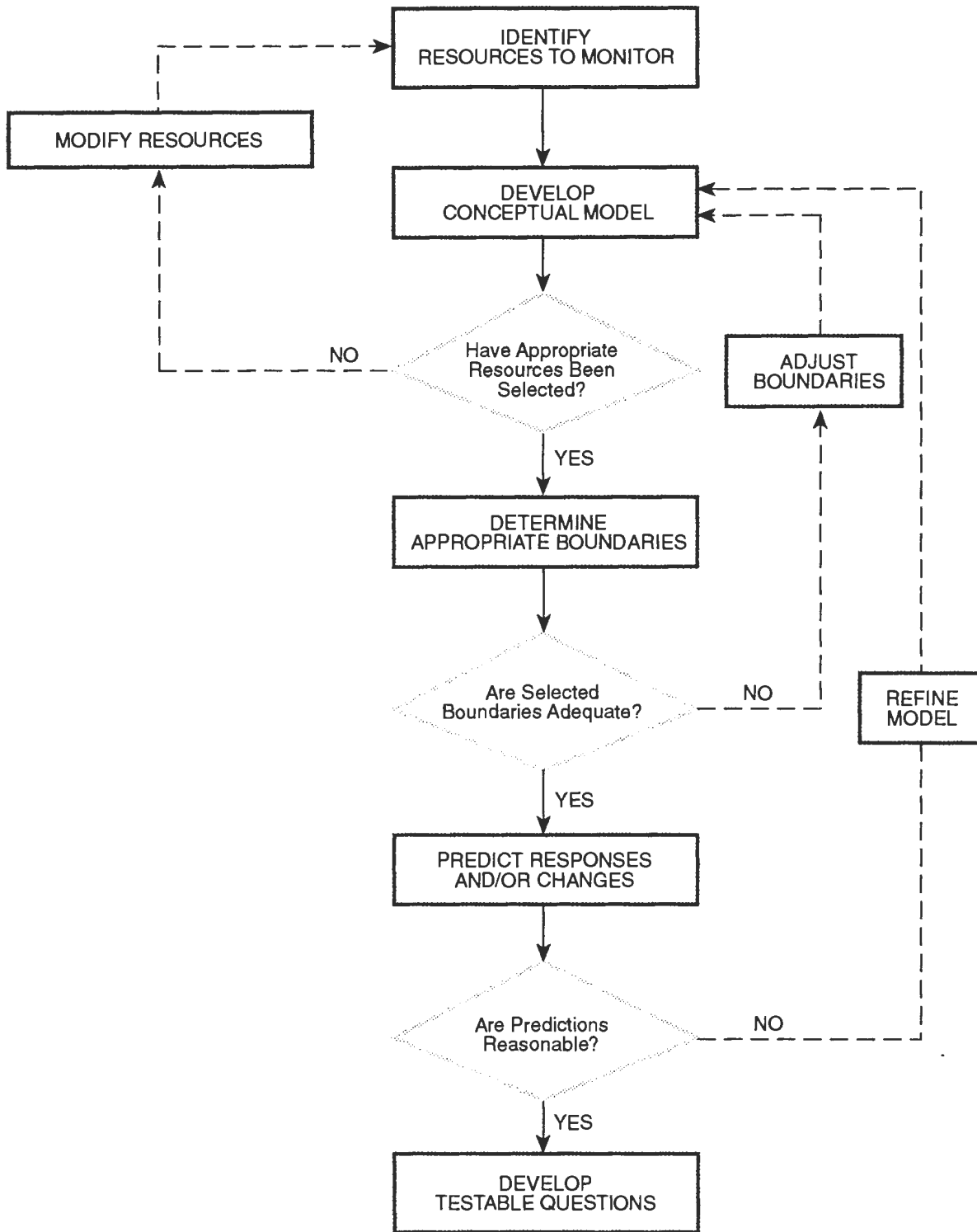
This conceptual plan was designed as a framework to address the questions raised in the Request for Proposal/Scope of Work that resulted in this contract. These questions are rephrased below. In the remaining sections of the plan, the answers to each question are discussed in more detail.

1. What process or mechanism would best assist the Trustee Council in determining monitoring priorities?
2. What are realistic goals and objectives for monitoring?
3. What resources and services should be monitored and why, given the goals and objectives of the monitoring?
4. Which clean-up, damage assessment and restoration studies contain elements that would best serve the intended monitoring program, and what are these elements?
5. Which surveys of services (e.g., recreation subsistence) contain elements that would best serve the intended monitoring program?
6. What consideration should be given to the relationships among different monitoring components (e.g., sediments, shellfish, fish, mammals, and birds), and how should they be integrated?
7. What relationships need to be established with other monitoring programs within the spill area and how should they be integrated?
8. What process (including infrastructure) should be considered to guide monitoring implementation and management?

Development of this plan began with a two-step interview process. A questionnaire was developed (see Appendix A) to establish user group expectations of the conceptual monitoring plan. Approximately fifteen people were interviewed, including the Restoration Team (RT), Restoration Planning Work Group (RPWG), and peer reviewers to establish the expectations of the plan. To gather input on specific elements that the conceptual plan was to address, a second questionnaire was developed (Appendix A), along with lists of draft goals, objectives, and strategies for the monitoring program and draft criteria for setting priorities. Approximately fifty individuals were queried, (see Appendix B for the list of those interviewed), including RT and RPWG members, peer reviewers and principal investigators.



**Figure 2.**  
**Framework for Three-Phased**  
**Approach to Monitoring**



Source: Adapted from NRC 1990.

**Figure 3.**  
**Framework for**  
**Defining Study Strategy**

These interviews were synthesized to form a preliminary draft plan. To refine the preliminary plan, a three-day workshop was held in Anchorage, Alaska to confirm the following:

- Establish that the intent of the RPWG was met with the development of the preliminary draft plan, confirm the workshop format and receive RPWG's comments for development of the final plan [Day One].
- Conduct key informant interviews with peer reviewers/experts to address the following issues [Day Two]:
  1. Identify what constitutes recovery.
  2. Prioritize the monitoring program goals and objectives.
  3. Determine whether strategies address the objectives.
  4. Develop a mechanism for prioritizing the resources and services to monitor.
  5. Identify the strengths and weaknesses of the proposed data management network.
  6. Discuss the management structure for monitoring.
  7. Review other monitoring programs.
  8. Identify stresses known to cause population effects.

In Day One of the workshop it was determined that issues one, two and three were of the greatest concern, so these were the primary focus for Days Two and Three.

A brainstorming session with those peer reviewers who were not being interviewed was held concurrent with the key informant interviews. This session was focused on setting monitoring activity priorities, and reviewing other monitoring programs.

- Provide a working forum with participation of the user groups (see Appendix C for a list of participants) [Day Three]. The focus included establishing:
  1. The overall goals of the monitoring program
  2. Recovery endpoints for injured resources and services
  3. The criteria to be used in evaluating monitoring activities
  4. A mechanism for prioritizing monitoring activities

The information gained at the workshop was then used to develop a framework for Phase 2 of the monitoring. Guidance for Phase 2 is provided in the sections to follow.

## **1.6 PLAN ORGANIZATION AND CONTENT**

This plan is divided into nine sections. It begins with this introductory section, which provides background for the program, suggests the value and use of monitoring, lists elements of the conceptual plan, and outlines the approach in developing the plan. Additionally, it lists

the specific questions posed in the scope of work agreement for development of the conceptual plan. This is followed by the definitions of recovery and the three monitoring types (Section 2), and the goals and objectives of the recovery monitoring program, as well as the strategies to meet them (Section 3). A discussion on the conceptual methodology, including identification of the injured resources and services and mechanisms for prioritizing monitoring activities is presented in (Section 4). Monitoring recovery endpoints for each injured resource and service are identified and discussed in this section. Section 4 also identifies and applies criteria to prioritize resources and services to monitor and provides information on the linkages between resources and services. Both can be further developed with resource- and service-specific conceptual models, as recommended. Guidance on sampling design, with resource- and service-specific information, is provided in Section 5. Section 6 contains information on other monitoring programs. Monitoring program management is covered in Section 7, while overall recommendations are presented in Section 8. Section 9 lists the references cited.

## 2. DEFINITIONS OF RECOVERY AND MONITORING TYPES

### 2.1 RECOVERY

Recovery is difficult to define. Following the *Exxon Valdez* oil spill, recovery of the various natural resources, and the services they support, has occurred at variable rates for different resources. Recovery will vary across the spill area and between populations of a resource. Thus, recovery will be occurring at different rates for individual resources and services and at different locations.

In the conceptual monitoring plan, the term recovery means a return to the estimated levels of populations/conditions *had the spill not occurred*. Recovery of resources and services can occur through natural biotic and geomorphic processes (except archeological resources) as well as through restoration or manipulation of existing conditions. Recovery of services may also include replacement or enhancement of affected resources and services.

For specific resources and some services, recovery to predicted "no-spill" levels may not occur for many generations of the species, if ever. For example, the *Exxon Valdez Oil Spill Draft Restoration Plan Summary of Alternatives for Public Comment* (Exxon Valdez Oil Spill Restoration Office [EVOS Office] 1993) includes time estimates for natural (unassisted) recovery of injured resources ranging from already recovered (bald eagle) to many decades (common murre), with "unknown" listed as time to recovery for 6 of the 18 resources considered. Examples from the *Summary of Alternatives for Public Comment* (EVOS Office 1993) include the following: archeological resources cannot recover; black oystercatchers may take several decades to recover; marbled murrelets recovery estimates are unknown. Additionally, it may take ten years to discern actual recovery from natural variation or background noise. Other factors (stresses), both natural and anthropogenic, influence resources, services, and ecosystems. Resources and services respond to multiple stimuli and the response to anthropogenic influences becomes superimposed over natural variability in a way that can preclude generalizations from resource to resource, habitat to habitat, and service to service. Thus, a return to no-spill conditions may not be realistic or feasible. Recovery of a resource will most likely be some steady state of conditions—an equilibrium that takes into account natural variation—and this may differ from conditions that existed before the spill.

Ideally, "complete recovery" of resources would include the presence of resources at the locations, in the abundances, with the population age-class structure, biomass, and species interactions had no spill occurred.

"Complete recovery" of services would include the use of the injured area by the original user groups, to the use levels, and with the attitudes prevailing had no spill occurred.

Resource or service enhancement may also occur through ongoing restoration activities. Enhancement goes beyond recovery; for example, it might include establishment of a population beyond the estimated no-spill level, or increased numbers of users beyond the no-spill levels.

For monitoring results to be used as an effective decision-making tool, it is necessary to establish monitoring and recovery endpoints for resources and services to be monitored (see Section 4.3.3). It may be necessary to define an achievable or "acceptable" level of recovery that may be less than an "ideal" or "complete" recovery.

Because baseline or pre-spill information was not available for many resources and services, clearly defining the original conditions for some may not be feasible. Thus, we must identify other criteria for evaluating recovery. Pragmatically, recovery may be evaluated by investigation of only a sample of the resources, habitats, and services affected by the oil spill and over a limited geographic area. Thus, it may be necessary in Phase 2 to identify key taxa and representative services that can adequately assess a spectrum of the injured resources and services.

## **2.2 MONITORING TYPES**

As noted earlier, this plan covers three types of monitoring: recovery, project, and long-term monitoring. It is critical that the monitoring activities occurring under each monitoring type be designed and coordinated with one another. Further definition of each monitoring type is provided below.

### **2.2.1 Recovery Monitoring**

Recovery monitoring is the monitoring of both assisted and unassisted recovery of injured resources and services. The primary focus of this plan is on recovery monitoring: determining both when recovery has occurred and the recovery rate. In some cases, natural recovery will be indistinguishable from assisted recovery, or assisted recovery will be an element of overall recovery. For example, the effect of a fish ladder on a particular stream to assist in the recovery of sockeye salmon may be measurable within that particular stream system (see project monitoring below), but its effect on the sockeye population as a whole, throughout the spill area, may not be distinguishable. Elements of recovery monitoring may extend into long-term monitoring, and general parameters, such as climatic data and identification of stresses, may be elements of both types of monitoring.

### **2.2.2 Project Monitoring**

Restoration activities (i.e., activities that involve manipulation to assist in the recovery of resources and services) may have a monitoring component to determine whether they are effective; for our purposes this is termed *project monitoring*. Project monitoring evaluates the

effectiveness of specific restoration activities. In this sense, project monitoring must be of discrete populations or areas, in order that cause-and-effect relationships can be established. For example, the restoration activity affects a single colony of murre, a pod of killer whales, or salmon recruitment on one stream as in the example above. The decision about restoration activities that need to be monitored will be based on the Trustee Council's review of ongoing and proposed restoration studies. Those selected for potential monitoring can then be reviewed in light of the objectives and strategies described in Section 3. Restoration activities and project monitoring may act as anthropogenic stresses to the resource they are meant to assist, as well as to other injured resources or services. In evaluating restoration activities to implement and/or to monitor, the consequences to other resources and services should be considered.

### **2.2.3 Long-term Monitoring**

Long-term monitoring will follow trends and cycles in the distribution and abundance of injured resources and the quality and quantity of lost or reduced services in the spill area. Monitoring of this type will also target species important in the food webs of injured species (e.g., forage fish) and habitats important to injured species (e.g., intertidal, uplands) to assess the overall health of the affected ecosystem. Monitoring conducted over entire life cycles for some resources (20 years or more) will be useful in designing effective strategies for long-term management of injured resources and lost or reduced services. Additionally, long-term monitoring will improve the information base (ecological and human uses) upon which impacts of future disturbances may be assessed.

We cannot collect all the information that would be useful in this context, because the combined cost of monitoring each important ecological component or human use will greatly exceed the funds now available. Prioritizing long-term monitoring activities will be guided, in part, by which types of data were lacking and would have been useful in assessing the nature and extent of injury following the oil spill. Prioritization will also be facilitated by identifying indicator resources, habitats, or services that are sensitive to change and that may be indicative of change in other populations and communities or services.



### 3. GOALS, OBJECTIVES, AND STRATEGIES

Defining monitoring goals and objectives is key to the successful development of a monitoring program. The overall goals of monitoring, as stated in the *Exxon Valdez Oil Spill Draft Restoration Plan Summary of Alternatives for Public Comment* (EVOS Office 1993) (referred to henceforth as draft Restoration Plan), are to develop a comprehensive and integrated monitoring program that will:

- Follow the progress of both natural and assisted recovery
- Establish an ecological baseline from which future disturbances can be evaluated

These broad goals have been further broken down into the specific goals, objectives, and strategies described below. The objectives reflect the general consensus of many individuals, including RT and RPWG members, peer reviewers and principal investigators. The objectives, as stated, are comprehensive. Resource- and service-specific objectives will need to be defined in Phase 2 of the monitoring program, when the bounds (e.g., physical, technical, social, political, and financial) of the monitoring program are set. With each subsequent phase of the monitoring program, as well as during proposal review and throughout actual monitoring, activities and documents should be reviewed to determine how well objectives are being met.

As mentioned, Section 3.1 outlines goals, objectives, and strategies that relate to the overall quality of the monitoring program; sections 3.2 and 3.3 present those goals, objectives and strategies that are specific to different types of monitoring.

#### 3.1 GENERAL MONITORING PLAN

##### 1. Goal

Scientifically and publicly credible monitoring program.

##### Summary of Goal

The monitoring program will be scientifically and publicly credible only if the individual projects are well thought out, planned, and executed. Variability and uncertainty can be dealt with and minimized by the use of preliminary studies or historical data, and reliable sampling and analytical methodologies. The plans for the individual monitoring projects need to be subject to peer-review prior to project initiation, as well as periodically throughout the project. All projects should also meet specified quality assurance and quality control (QA/QC) guidelines.

## Objective

- Ensure a credible monitoring program that, if possible, limits the monitoring to testing hypotheses. The program should also set project-specific, acceptable limits on the precision and accuracy expected (sample variability) and account for natural variability for program elements. [Monitoring activities that cannot test hypotheses should explicitly state what they intend to accomplish and identify the problem and question(s) they intend to address.]

## Strategies

- Specify monitoring requirements in the RFP. For example, submittals must be formulated with testable hypotheses.
- Use a timely peer-review system for proposals and reports and review these products for scientific credibility and merit, technical feasibility (including their ability to detect change), and how useful the data are to resource managers and the public.
- Review monitoring proposals and assess methods and reports to ensure that, whenever possible, testable hypotheses are stated and uncertainties (i.e., sample and natural variation) are addressed.
- Where needed, develop, or request development of, methods for monitoring.
- Develop a framework for QA/QC.
- Take public opinion and perception into account when developing the monitoring plan.
- Establish forums (e.g., scientific, community and agency participants) to evaluate monitoring study effectiveness.
- Establish a design and evaluation team of statisticians and modelers to provide a uniform, high level of expertise to support those who will conduct the monitoring.

## 2. Goal

- An accessible and/or integrated, well-designed database.

### Summary of Goal

Data accessibility is critical for the monitoring to be of any value to resource managers, scientists, and the public. To be an effective tool for decision makers and investigators, a catalog of the monitoring data, as well as other spill-related data, should be centrally located and accessible to the various user groups. A centralized cataloging system would allow for the past, ongoing, and future data collected to be accessed. This would not only maximize the information gained from the spill but also allow comparisons between and within resources and services. Additionally, the database must be designed properly for easy retrieval of data useful to scientists, agencies and the public.

### Objectives

- Centralize existing *Exxon Valdez* monitoring, damage assessment, and restoration data.
- Centralize or coordinate existing monitoring and resource management data and information that may be useful in understanding recovery of resources and services injured by the oil spill.
- Ensure accessibility and retrieval of monitoring data by the various user groups.

### Strategies

- Develop a well-designed centralized, computerized catalog or library of databases that should include, but not be limited to: contact name/agency, parameters measured, resource or service studied, and (when possible) the summary statistics calculated.
- Identify and build an efficient structure with well-defined variables/fields, headers, linkages, selection tools, and reporting forms.
- Code existing and future *Exxon Valdez* oil spill databases with a common link for location/site and resource or service so that information on resources or services is retrievable by a unique identifier, as is information on a location/site.

- Provide guidelines to principal investigators for standardizing components (such as resource or location/site codes and reporting units) for ease in adding and retrieving data.
- Use a well-designed system that is user-friendly and provide step-by-step instructions on how to access and retrieve information from the catalog of databases.
- Determine the computer software and hardware necessary.
- Design a flexible system to accommodate additional fields or parameters and respond to unforeseen needs as new information becomes available.
- Identify the potential needs of the user groups, including oil spill response teams, NRDA researchers, principal investigators, and public users.
- Identify an individual to oversee the centralized catalog, including acquisition of databases and programming.
- Ensure that information is centrally located to facilitate its accessibility.
- Integrate the database with interpretive and analytical tools (i.e., routines/programs) that allow information retrieval in formats useful to users. Information products should be useful to the various users, such as data sets for further analyses, summary tables, statistical comparisons, and graphical illustrations.

### 3. Goal

- Information for long-term management of injured resources and services.

#### Summary of Goal

Monitoring results provide a tool for decision makers to determine which resources and services are recovering on their own and whether the recovery rate is acceptable, which resources may never recover, and which may recover with human assistance.

#### Objective

- Provide information useful to decision makers.

### Strategies

- Collect long-term data documenting recovery of injured resources and services.
- Ensure accessibility of monitoring data to resource agency managers and other decision makers, investigators, and the public.
- Develop models to evaluate the data in forms that are useful to various users.

#### 4. Goal

- Establish a link between project approval and funding for that project.

### Summary of Goal

A link between project approval and project funding needs to be established; a program designed to determine if recovery is occurring should not be curtailed due to a funding shortage part way through the program. The project approval decision process needs to include steps for guaranteeing funding, with feedback mechanisms that still allow for project review.

Multiple years of monitoring will be necessary in many cases to ensure that injured resources and services have recovered. Recovery of several of the resources may not be detectable within a ten-year period due to a variety of factors (e.g., time to reproductive maturity and fecundity). Due to this constraint, guarantee of a long-term funding source needs to be established prior to implementation of some monitoring programs.

Additionally, even for resources where recovery can be measured in less than ten years, the programs will likely involve multiple-year studies, and/or periodic monitoring. To ensure that funding will be available to complete studies requiring periodic monitoring over several years, it will be necessary to establish a link between project approval and funding that ensures a long-term funding mechanism. One funding link or method is to establish an endowment to fund activities after Exxon payments end.

### Objectives

- Fund multiple years of monitoring.
- Make commitments of multiple-year budgets for specific program elements.

- Develop cost estimates for the life of the overall program and specific program elements, and plan accordingly.
- Provide feedback mechanisms for program review, both technical and financial.

### Strategies

- Establish an endowment to be used for multiple years of monitoring (i.e., greater than ten years).
- Plan budget based on cost estimates and invest settlement funds accordingly, to ensure funding is available for the life of the project and program elements.
- Award contracts for multiple years of monitoring to guarantee that a project/program will continue for the time necessary to address the questions it posed.
- Make contract awards subject to financial and technical review and modification should they not be addressing the questions originally posed.

### 5. Goal

- Consistency and timeliness in data reporting.

### Summary of Goal

To maximize the usefulness and compatibility of the monitoring data and ensure the timely submittal of monitoring results, standardize the reporting requirements, both format and schedule.

The guidelines developed will not dictate which methods investigators must employ to study their resource or service, rather the more general aspects to follow, such as reporting data in metrics and utilizing one of five possible software packages as a database software. For scheduling, a requirement can be instituted such as receipt of deliverables within four months after the end of the field season or after the analytical laboratory results are obtained.

### Objectives

- Provide proposal and reporting guidelines (covering components such as publishing requirements, standardization of units, use of convertible software, status reports, QA/QC requirements, and ideas on statistical methods to employ).

- Establish a method for ensuring timely submittal of deliverables.

### Strategies

- Require periodic one-page progress reports and project-end reports with date of deliverables dependent on the resource- and/or service-specific studies.
- Develop guidelines (covering components such as publishing requirements, standardizing units, convertible software, status reports, QA/QC requirements, and ideas on statistical methods to employ) for principal investigators to follow.
- Develop recommendations for RFP and contract language that set specifics for reporting, schedule commitments, and incentives or disincentives for meeting or not meeting schedule, quality, or financial obligations.
- Establish general reporting requirements for information potentially useful to a variety of programs, such as collection of climatic data.

## 6. Goal

- Program design that provides a feedback mechanism and integration with other monitoring programs.

### Summary of Goal

Throughout monitoring, feedback mechanisms will be important to ensure that monitoring is effective in determining if recovery is occurring at an adequate rate and to ensure coordination/integration with existing monitoring programs and others, as they come on line. These mechanisms should be instituted at the design phase to ensure they are accomplished and that there is no duplication of effort. Mechanisms are also needed for adaptively changing the monitoring strategy and monitoring components.

### Objectives

- Establish a method for ensuring feedback/evaluation of the monitoring program, and for coordination/integration with other programs.
- Establish a means for all investigators to allow their programs to be reviewed and modified or adapted to changes in strategy.

### Strategies

- As a proposal requirement for monitoring elements, require that the submitter identify existing programs with which to coordinate and ask how they propose to accomplish this.
- As a proposal/contract requirement, institute a feedback/evaluation process to ensure that the monitoring element is meeting its objectives, include language that the program must adapt to changes in monitoring strategy and/or redirection of effort.

### 7. Goal

- Dissemination of information to the user groups.

### Summary of Goal

Although not necessarily a component of the monitoring program, if the monitoring results are to be useful, they must be available to the users.

### Objective

- Identify a mechanism for timely dissemination of information that is available and understandable to the various users.

### Strategies

- Through the NRDA process and ongoing restoration activities (including public comments), generate a list of the user groups and the type of information they need (e.g., summary information and data on specific resources and services).
- In the proposal/contract development, require that respondents agree to: (1) the submittal of summaries of their programs; (2) submittal of reports and data at scheduled intervals and in a set format; (3) attendance at forums to share information; (4) identification of data from other monitoring elements that would be useful to them (e.g., mussel contamination data may be useful to those studying sea otters); and (5) presentation of information in forms appropriate to the audience (e.g., technical, decision maker, public).
- Through an accessible and easy-to-use centralized database, provide integration, interpretation and presentation of results in forms appropriate to the various user groups.



## 3.2 RECOVERY AND PROJECT MONITORING

Recovery monitoring covers both assisted and unassisted recovery of injured resources and services. Project monitoring covers the monitoring of select restoration activities and their effect on discrete populations. Despite the differences between these two types of monitoring, the goals are the same; thus, they are discussed together.

### 1. Goal

- Prioritization of resources and services, and specific elements of each to monitor.

#### Summary of Goal

Given that monitoring funding resources are finite, a series of decisions must guide development of monitoring programs and the process of selecting among potential resources and services.

#### Objective

- Develop a method for prioritizing monitoring activities and determining the elements and recovery endpoints to be monitored.

#### Strategies

- Develop selection criteria to prioritize the resources and services to monitor.
- Use teams of experts to establish priorities for recovery monitoring by evaluating how well the injured resources and services meet criteria.
- Evaluate monitoring programs in light of public opinion/perception (phases 1 and 2 of the monitoring program).
- Develop criteria to identify resource- and/or service-specific monitoring activities (e.g., the life stage, behavior attribute, or population dynamic) and sampling designs (including statistical review) that are likely to document the success or failure of recovery (phases 1 and 2 of the program).
- Evaluate potential monitoring activities by using population models.
- Obtain cost estimates for conducting specific monitoring activities (Phase 2 activity).

- Determine a common benefit currency (e.g., time to endpoint), then evaluate the cost-effectiveness of the recovery monitoring options (Phase 2 activity) and evaluate monitoring priorities.

## 2. Goal

- Develop a mechanism to document natural or assisted recovery and the rate of recovery.

### Summary of Goal

To monitor recovery over a long period (e.g., ten years or greater), some monitoring projects should be designed in serially repeating phases or at periodic intervals. These projects could continue as long as deemed necessary to determine whether recovery has occurred, as long as satisfactory work was completed. Satisfactory work would be defined independently of the results obtained. Some resources near oil spills in cooler temperate climates have shown significant effects of spills at least ten years after the event (Chan 1977; Conan 1982; Cretney, et al. 1978; Elmgren, et al. 1983; Linden, et al. 1979; Teal and Howarth 1984). Provisions should be made for selecting projects that continue for many years. Additional unsampled and/or undiagnosed spill injuries may be discovered and may need to be included in the monitoring plan at a later date. Additionally, indicators may not necessarily be determined before the sampling program begins, thus the program should be flexible enough to add and discontinue projects.

### Objectives

- Establish a monitoring program to determine recovery rates.
- Design a flexible monitoring program to accommodate redirection of efforts as new information becomes available.
- Define recovery endpoints for injured resources and services.
- Evaluate whether recovery rates are acceptable.

### Strategies

- Propose to the Trustee Council acceptable rates of recovery and recovery endpoints for each resource and service, that are based on input from resource experts and/or population dynamic specialists (Phase 1 and 2 of the program).

- Use a team of statisticians biologists, chemists and service experts, to identify appropriate intervals (monitoring frequency) for determining recovery of a resource and service over time and space (Phase 2 activity).
- Where possible, determine the influence of other perturbations (natural or anthropogenic) on recovery (e.g., winter kill, other die-offs, predation, human disturbance, climatic changes such as El Niño, and commercial fishing pressures) (Phase 2 and 3).
- Use existing data to assess baseline conditions (pre-spill, control, and/or damage assessment and restoration control site data).
- Use existing data (from the spill and from other programs) for developing recovery monitoring methodologies.
- Implement a periodic review system that allows for redirection of efforts.
- Involve scientific experts and resource and service specialists during development of the monitoring program (all phases of the monitoring program).
- Develop a monitoring scope that encompasses the strategies above.
- Compare the resource- or service-specific acceptable recovery rate to the monitoring data obtained to reach a decision point: If rate of recovery is acceptable, evaluate the need for continued monitoring. If the rate of recovery is unacceptable, evaluate restoration alternatives and/or research opportunities.
- If a restoration activity is involved (project monitoring), consider the influence (positive or negative) it has on other resources and services.

### 3. Goal

- Establish linkages among resources and services to better understand recovery.

#### Summary of Goal

Although the tendency of monitoring is to focus on individual taxa, the *Exxon Valdez* oil spill had an impact on a large geographic area with many different communities and trophic interactions. Due to the nature of the affected area, interactive and interdependent processes were disrupted, altered, or destroyed. However, the complexity of ecosystems makes them difficult or impossible to study as whole systems. The study of recovery of such a large association of communities (animals and human) would be difficult and cost prohibitive. However, if linkages among

resources and services are understood, it may be possible to infer recovery of the system from monitoring focused on key components of the ecosystem.

#### Objective

- Base the recovery monitoring plan on linkages that incorporate knowledge of trophic interactions, spatial and temporal variability, and other factors.

#### Strategies

- Determine linkages and interactions (positive or negative) among resources and services by evaluating available information.
- Develop resource- and service-specific conceptual models that include biological, physical, social, and cultural interactions and processes.
- Select resources and services for monitoring that whenever possible, are linked via trophic interactions that can be used to draw inferences about similar resources and services.
- Collect the available information on resources and services and produce a concise summary.

### **3.3 LONG-TERM MONITORING**

Long-term monitoring is conducted to study changes or trends in resource distributions and abundances or the quality and quantity of services over time and space. Information gathered can then be used to develop a baseline from which disturbances can be detected.

#### 1. Goal

- Increase knowledge of natural and anthropogenic stresses to aid in development and interpretation of monitoring elements.

#### Summary of Goal

Factors influencing the recovery of resources and services need to be considered to interpret the monitoring results. To assume that the oil spill is the sole perturbation on resources and services will skew analysis and conclusions of the monitoring. Many other natural and anthropogenic factors influence ecosystems and the recovery rates of resources and services.

### Objectives

- Identify potential and known natural stresses to resources and services, such as El Niño or winter kill.
- Identify potential and known anthropogenic stresses to resources and services, such as overharvest, oil spill, and harassment.

### Strategies

- Specify as a contract requirement (part of scope of work) that principal investigators include a reporting section discussing anthropogenic and natural stresses on the resources or services they are studying and how these might influence the results obtained.
- Develop resource- and service-specific conceptual models that include biological, physical, social, and cultural interactions and processes.

## 2. Goal

- Increase knowledge of temporal and spatial variations in population distribution and abundance.

### Summary of Goal

To detect change that is outside the range of natural variation, it is necessary to establish the bounds of natural variation. Long-term monitoring is required to define these bounds. Once established, monitoring should then be able to detect changes that extend beyond the bounds of natural variation.

To detect change between control and treatment sites, sampling must include sites or units that are replicates or nearly replicates. This allows differences between the two to be interpreted.

### Objectives

- Develop a monitoring program to detect changes in biological and/or physical parameters that fall outside the range of natural variability.

- Develop a monitoring program with an appropriate number and distribution of sampling units. If a perturbation should occur to a sampling unit, it could then be detected in comparison with those areas or units that were not affected.
- Follow long-term trends to provide baseline information for future perturbations.

### Strategies

- Review past and present long-term monitoring programs to identify sampling matrices (e.g., water, sediment, tissue) and parameters useful in detecting environmental change.
- Review past and present NRDA and restoration data to identify resources with population effects attributable to the oil spill.
- Review past and present NRDA and restoration methodologies to ensure that the monitoring design sets up appropriate control sites.
- Evaluate which recovery monitoring programs should evolve into long-term monitoring programs.
- Select physical, chemical, and/or biological indicator parameters for monitoring temporal and spatial changes in environmental quality based on parameters that are sensitive to perturbations (i.e., those that will show a change), and that are well understood (i.e., a solid basic knowledge of natural variation, and/or thorough knowledge of life history).
- Evaluate the efficiency (i.e., cost-effectiveness, ability to dovetail with other studies, frequency of sampling required) of monitoring these parameters.
- Design and implement a program that encompasses the above strategies.

### 3. Goal

- Increase knowledge of linkages between physical, biological, and/or chemical parameters, as well as social and cultural interactions.

### Summary of Goal

It is necessary to select indicator parameters for monitoring because it is not economically or logistically feasible to conduct long-term monitoring of all resources and services. Indicators should enable inferences to effects on other resources,

services, or parameters, but first the linkages between the parameters must be established.

### Objectives

- Identify and understand linkages between physical, biological, and/or chemical parameters, as well as social and cultural interactions.
- Enable inferences to be made about higher trophic level or ecosystem exposure/health.
- Enable inferences to be made about recovery of resources and services not directly monitored.

### Strategies

- Wherever possible, determine links, between the parameters monitored by evaluating available data on physical, biological, and chemical features. This should include exposure mechanisms (the coupling of monitoring multiple trophic levels with studies of the physical and chemical processes) as well as social and cultural interactions.
- Select parameters that are linked via trophic levels or that can be used to draw inferences about similar resources or services.
- Evaluate selected parameters in relation to the geographic location and physical setting (e.g., enclosed embayment) to determine if they will be effective indicators.

## 4. CONCEPTUAL METHODOLOGY

The injured resources and services that might be monitored, and the mechanisms for prioritizing monitoring activities are identified below. Since an overriding factor controlling the extent of monitoring is the funding available, the Trustee Council will ultimately determine which monitoring activities to fund.

### 4.1 RESOURCES TO MONITOR

The settlement requires that use of restoration funds be linked to resources and services injured as a result of the *Exxon Valdez* oil spill. Resources injured are identified in the draft Restoration Plan and listed below. Resources are divided into those injured at the population level (direct effects), those injured indirectly, and other injured resources. Mechanisms for prioritizing the list of injured resources and services are discussed. The resources and services will be prioritized for recovery monitoring during Phase 2 following procedures outlined in Section 4.3.4.

Resources injured at the population level include:

- Mammals
  - Sea otters
  - Harbor seals
- Birds
  - Common murre
  - Marbled murrelet
  - Pigeon guillemot
  - Harlequin duck
  - Black oystercatcher
- Fish
  - Sockeye salmon
- Community Assemblages
  - Intertidal biota
  - Subtidal biota



Resources injured but that did not appear to experience a population decline as a result of the spill include:

- Mammals
  - Killer whales
  - River otter
- Birds
  - Bald eagle
- Fish
  - Cutthroat trout
  - Dolly varden
  - Pink salmon
  - Pacific herring
  - Rockfish

Other injured resources include:

- Archeological sites and artifacts
- Designated wilderness areas

Other resources may have been injured either directly or indirectly as a result of the oil spill, but either they were not studied during the NRDA process or were not identified by the Trustee Council in the draft Restoration Plan. The list of injured resources may change as monitoring results become available.

## **4.2 SERVICES TO MONITOR**

Injured services identified by the Trustee Council as important to monitor include:

- Commercial fishing
- Commercial tourism
  - Tour ships
  - Day tours
  - Hunting and fishing charters
- Passive uses (also called aesthetic, wilderness, intrinsic or non-use value)

- Recreation
  - Sport fishing
  - Sport hunting
  - Boating (motorized and sail)
  - Ocean kayaking
  - Hiking and camping
  
- Subsistence

The resources and services selected for monitoring may differ depending on the type of monitoring (recovery, project, or long-term). Long-term monitoring in particular may include resources and services not identified above.

### **4.3 MECHANISMS FOR ESTABLISHING MONITORING PRIORITIES**

Several mechanisms could be used for prioritizing monitoring activities associated with injured resources and services. Recommended approaches are to:

- Build consensus or ownership through participation of the various user groups
- Define the program goals, objectives and strategies
- Develop recovery endpoints
- Develop and apply criteria for evaluating monitoring activities
- Develop and apply conceptual models for injured resources and services

These mechanisms have been applied in development of this plan. They are further discussed below.

#### **4.3.1 Involvement of User Groups and Consensus Building**

The users (e.g., scientific community, resource managers, general public, and Trustee Council) of the monitoring information should be involved in defining the goals of the program and deciding monitoring priorities. Involving the user groups in various aspects of the monitoring program helps gain their support for the program. It may not be possible to reach a consensus among all users, but involvement promotes ownership and support of the program. As stated in the civil settlement, public involvement is an integral part of the restoration process. If the public is to feel that recovery has been successful and that the settlement monies have been used properly, their concerns and attitudes about allocation of resources for monitoring need to be identified and considered during public meetings, hearings, and other public participation forums.

#### 4.3.2 Development of Goals, Objectives and Strategies

Development of a sampling design can only occur after the goals and objectives are clearly stated. Thus, the first step in the development of a monitoring program is to define program goals and objectives. Then strategies for meeting the objectives can be developed. During development of this present plan, the goals, objectives and strategies for monitoring were defined through a consensus-building process with resource and service experts, principal investigators, the RT, and the RPWG. Public participation was achieved indirectly through involvement of the Trustee Council and their use of the public participation task force. The resulting list of goals, objectives, and strategies were presented in Section 3. During Phase 2 of the program, goals, objectives and strategies will be defined for specific resources and services. Hypotheses can then be developed for testing. Despite development of resource- and service-specific monitoring goals, the goals identified in this plan should not be forgotten. Review of the monitoring program should encompass determining if the goals outlined in this plan are being met.

#### 4.3.3 Recovery Endpoints

Although the Trustee Council will ultimately make the decision on monitoring priorities, two factors should influence the Council: recovery endpoints and public concerns. *Recovery endpoints* for each resource and service have been developed (Table 1). These should undergo review by resource and service experts. *Monitoring endpoints* should also be developed (i.e., resources or services may be monitored beyond the defined recovery endpoint under long-term monitoring).

Endpoints for long-term monitoring, which may include some of those for recovery monitoring, should also be developed. Monitoring should not necessarily cease once the recovery endpoint of a resource or service is attained. Continued monitoring may provide valuable information on ecosystem health and/or on the effects of further disturbances, and thus be an important element in a long-term monitoring strategy. The continuation of monitoring may also provide information on enhancement of resources and services beyond recovery. Continued monitoring beyond recovery should be evaluated on a case-by-case basis, and take into account agency and non-agency programs that may cover or impact the resource or service. Endpoints that would be useful for long-term monitoring to detect future perturbations are also indicated in Table 1.

Recovery endpoints specific to injured resources and services will be the measure for determining whether or not recovery has occurred. Endpoints will differ for each resource or service; in some cases, endpoints will differ by monitoring type. The vertical axis on Table 1 provides a list of resource and service endpoints developed through the workshop process described in Section 1.5. The ranges in definition for recovery endpoints is based on the definition of conditions existing prior to the *Exxon Valdez* oil spill, as discussed in Section 2 and further illustrated in Table 1. The horizontal axis of Table 1 is a list of the injured

Table 1. Matrix of recovery endpoints for Injured resources and services.

ENDPOINTS	INJURED RESOURCES AND SERVICES																											
	KILLER WHALE	SEA OTTER	HARBOR SEAL	RIVER OTTER	PISCAN GULL/BOAT	BLACK OYSTERCATCHER	COMMON MURRE	MARSHED MURRELET	HARLEQUIN DUCK	BAUD EAGLE	CUTTLEPOUT/TROUT	DOLLY WARDEN	SCOTTIE SALMON	PINK SALMON	PACIFIC HERRING	POCKLEWORM	ARCHAEOLOGICAL SITES/ARTIFACTS	INTERSTITIAL COMMUNITIES	SUBTIDAL COMMUNITIES	DESIGNATED WILDERNESS AREA	COMMERCIAL FISHING	COMMERCIAL TOURISM	PASSIVE USES	SUBSTANCE	RECREATION	MUSEUMS 3	FOUNDED REEF 2	
<b>Biological</b>																												
- Population Size	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
- Mean Population Size with Coefficient of Variation	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
- Reproduction/Recruitment	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
- Growth (Individual, Physical) Rate	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
- Physiological	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
- Population Equilibrium (Population Growth)	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
- Age Class Sex Structure	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
- Pre-spill Condition Adjusted for Change (Decline or Increase)	▲	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
- Mortality Rate	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
- Distribution (Density)	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
- Behavior																												
- Habitat Usage	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
- Community Structure (Diet, Taxa Richness, Community Taxa Richness)	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
- Population Growth Rate	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
<b>Physical/Chemical</b>																												
- Eliminate Oil as Plausible Cause of Negative Effect			●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
<b>Services and Archeological Resources</b>																												
- Reduction of Looting (Archeological)																	●	●	●	●	●	●	●	●	●	●	●	
- Usage Attained			●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
- Hydrocarbon Concentration No Longer Affects Organic Components of Sites(Archeological)																	●	●	●	●	●	●	●	●	●	●	●	
<b>Achievement of Compensatory Action (Related to Services Only)</b>																												
- Quantity (Is it enough?)																												
- Quality of Action																												
- Location of Action																												
- Perception of Action																												

1 Control sites can be within or outside the spill area (e.g., historical). Sites within the spill area will be given precedence over sites outside the spill area. For use of sites outside the spill area there needs to be justification provided.

2 Several of the endpoints for the injured resources and services can be considered for long-term monitoring. Those indicated on the matrix are noted because they may not be obvious.

3 Not included in Trustee Council's list of injured resources, but have interactions with several resources on the list.

● Pre-spill ■ Control <sup>1</sup> ▲ Long-Term <sup>2</sup> ◇ Perception/Value  
 NA Not Applicable

resources and services identified in sections 4.1 and 4.2. The judgement about whether an endpoint has been reached can be based on pre-spill conditions, on control site monitoring, and/or the perception of the resource and service users (see Table 1). Table 1 indicates that there is more than one recovery endpoint for the majority of resources and services. To determine whether recovery has occurred or is occurring, it is likely that more than one recovery endpoint will need to be considered when developing a specific monitoring program for a given resource or service. The choice of recovery endpoints will depend, in part, on the magnitude of the injury and the ability to monitor the endpoint, as well as costs and logistics. For example, attainment of the recovery endpoint for the pre-spill mortality rate for killer whales may not be directly measurable because carcasses generally sink. But the endpoint may be indirectly measured through monitoring population size and reproduction/recruitment.

Table 1 is only partially complete. Experts in all disciplines pertinent to the injured resources and services have not yet been involved in development and review of the table. The workshop mentioned earlier generally had no more than one or two experts present (and sometimes none) for a particular resource or service. Additional review of the recovery endpoints is needed (at least three experts) for each resource or service. The experts can evaluate and select recovery and monitoring endpoints that will yield the most meaningful information.

As noted earlier, not all potential recovery endpoints can be monitored. Endpoints may define recovery for a resource or service, but recovery may not be achievable in the foreseeable future. It will be important to communicate these limitations to the user groups, particularly the public, to explain why particular resources or services have not been included in the monitoring plan. In addition, if it is determined that a specific recovery endpoint cannot be measured, but the monitoring activity is necessary, then an explanation should be provided.

Finally, economic studies of damages to services have been completed by the Alaska Department of Law. These studies can aid in determining and defining endpoints for particular resources and services. To better understand the economic consequences of specific recovery monitoring and restoration activities, it may also be useful to include economists in the process of determining recovery and monitoring endpoints for services. The Trustee Council should consider completing the NRDA economic study and comparing it with the Department of Law study to determine which damage assessment projects may be most useful to the recovery monitoring process.

#### **4.3.3.1 Resource Endpoints**

The recovery endpoints for the resources and services identified at the workshop are presented in Table 1. Examples of endpoints for two of the resources and all of the injured services (those resources and services whose endpoints require information on the characteristics of the resource or service, as well as social, cultural, and religious values), are further described below. Endpoints for the biological resources are not discussed further in the plan because

many are self-explanatory, (i.e., the measurement of population size, mortality rate, distribution, etc). However, when considering biological endpoints, it is important to consider pre-spill conditions of resources (i.e., if populations were in decline prior to the spill).

### **Archeological Resources**

Archeological resources (i.e., archeological sites and artifacts) do not and cannot recover as can natural resources; therefore, permanent damage to archeological sites and artifacts can occur if they are not restored. In general, the damage to archeological sites and artifacts occurs through looting of sites and artifacts, erosion within and around sites as a result of clean-up activities, and by oiling. Thus, "recovery" endpoints for archeological sites and artifacts are associated with the nature of the injury and tied directly to restoration activities.

Two endpoints for archeological resources were identified in the workshop: (1) a reduction of looting of archeological sites and artifacts, and (2) the lowering of hydrocarbon concentrations so that they no longer affect organic components of archeological sites. Each of these endpoints could be evaluated using pre-spill data, by establishing control sites and/or through long-term monitoring.

With respect to looting, expert opinion indicates that sites in the spill area that have not already been looted are likely to be looted in the future. Additional looting could occur because there is increased knowledge of the location of sites as a result of clean-up activities. In addition, graffiti on existing archeological sites and structures can promote additional looting. To prevent further damage, existing graffiti needs to be removed and looter holes filled.

### **Designated Wilderness Areas**

The oil spill has changed peoples perception of the wilderness areas from that of pristine to effected habitats. The injury to this resource is the change in perception. The perception has value even if the individual with the perception never visits wilderness areas in the spill area. Experts agree that regaining the original perception is not realistic. Thus, an objective recovery endpoint for this resource may not be definable. However, lack of a clearly defined endpoint should not preclude consideration of this resource for monitoring.

Experts suggest that perceptions may be sufficiently changed by designating additional portions of Prince William Sound as wilderness. This designation is beyond the immediate scope of the monitoring program; the issue should be considered in the context of the entire restoration plan.

#### **4.3.3.2 Service Endpoints**

Defining recovery endpoints for services is difficult. A general endpoint could be defined as the point in time when there are no causal links between the condition of the service and the oil spill.

##### **Commercial Fishing**

Physical and biological factors, as well as fisheries management actions, influence commercial fish harvests. Determining injury to commercial fisheries is complicated by variations and fluctuations in the fishing industry and other practices (e.g., input from hatcheries). As a result, experts believe that designating one recovery endpoint for commercial fishing activities would be very difficult. Experts involved in the workshop identified two possible endpoints that could be related to commercial fishing. One endpoint is to reach pre-spill conditions where fish runs are able to support commercial fishing levels. This endpoint could be determined using pre-spill fish return and harvest data, along with an evaluation of users' perceptions associated with commercial fishing. The second endpoint relates to attaining levels of use similar to use levels before the oil spill. This endpoint could also be evaluated using pre-spill escapement or harvest data collected by Alaska Department of Fish and Game (ADF&G). These endpoints may translate to restoration activities. A third endpoint which relates to recovery monitoring (versus project monitoring) is to reach a point where there is no documented oil effects on fishing.

##### **Commercial Tourism**

Several forms of commercial tourism were injured by the oil spill. These include tour ship cruises, day tours, and hunting and fishing charters. At the workshop, experts indicated that one possible endpoint for these commercial tourist activities is for reservations and bookings with companies that provide these activities to return to pre-spill levels. Such estimates of pre- and post-spill levels should, however, consider other factors that may influence tourism (i.e., the state of the economy, weather trends, and projected growth in tourism in the absence of the spill).

##### **Passive Uses**

Damages associated with passive uses (also know as wilderness, intrinsic or non-use values) of the environment are difficult to demonstrate and quantify. Recovery endpoints associated with passive uses (e.g., the quality and location associated with the passive use) need to be defined by the characteristics of these uses as well as by the perceptions and values that people place on the environments that provide the uses.

## **Subsistence**

Injuries to subsistence harvests are well defined. There are concerns with contamination of resources among individuals and communities dependent on subsistence harvests. Two endpoints identified at the workshop could be considered in determining recovery of subsistence harvests. The first is that recovery occurs when subsistence users believe that the resources they depend on are no longer injured by the oil spill. This could be evaluated using pre-spill data or hydrocarbon data, as well as through an evaluation of perceptions (i.e., satisfaction with the type and level of subsistence activities) among subsistence users. The second endpoint could be to attain use levels of subsistence resources similar to the use levels before the oil spill. Alaska Department of Fish and Game (ADF&G) surveys of subsistence use could provide pre-spill baseline information.

## **Recreation**

Recreational activities in the spill area consist of sport fishing, sport hunting, motor boating, ocean kayaking, sailing, hiking, and camping. In general, two recovery endpoints for recreational activities were identified by experts at the workshop. The first is that recovery occurs when recreational users believe that the resources supporting recreational activities are no longer injured by the oil spill. This endpoint could be evaluated by using pre-spill information and surveys to evaluate perceptions about the resources that support the service. The second endpoint is to have the level of use return to a level similar to that before the spill. Pre-spill data for some recreational activities could be used to evaluate the second endpoint. For example, there is anecdotal information on pre-spill use levels of ocean kayaking that could be compared to post-spill ocean kayaking use. Recovery endpoints specific to each type of recreational service should be developed by service experts during Phase 2 of the monitoring program.

### **4.3.4 Criteria for Selecting and Evaluating Monitoring Activities**

The criteria identified in Table 2 are to assist the Trustee Council in prioritizing which resources and services to monitor and which studies of these resources and services meet the goals and objectives of monitoring. Resources and services to be monitored should be prioritized using these criteria, since it is doubtful that funding will allow all resources and services to be monitored. The process of setting monitoring priorities is illustrated in Figure 4. Prioritization can be accomplished through application of the criteria presented. The criteria should be applied by several resource and service experts.

Socioeconomic concerns may also be an element that the Trustee Council reviews. In part, the socioeconomic criteria or value of a monitoring action would be what society is willing to pay for the information gained. If the monitoring information can be linked to a substantial improvement in the probability of avoiding injuries from another catastrophic event, the information may be highly valued. However, if the information helps resource managers make small improvements in the population size of an already abundant population, the



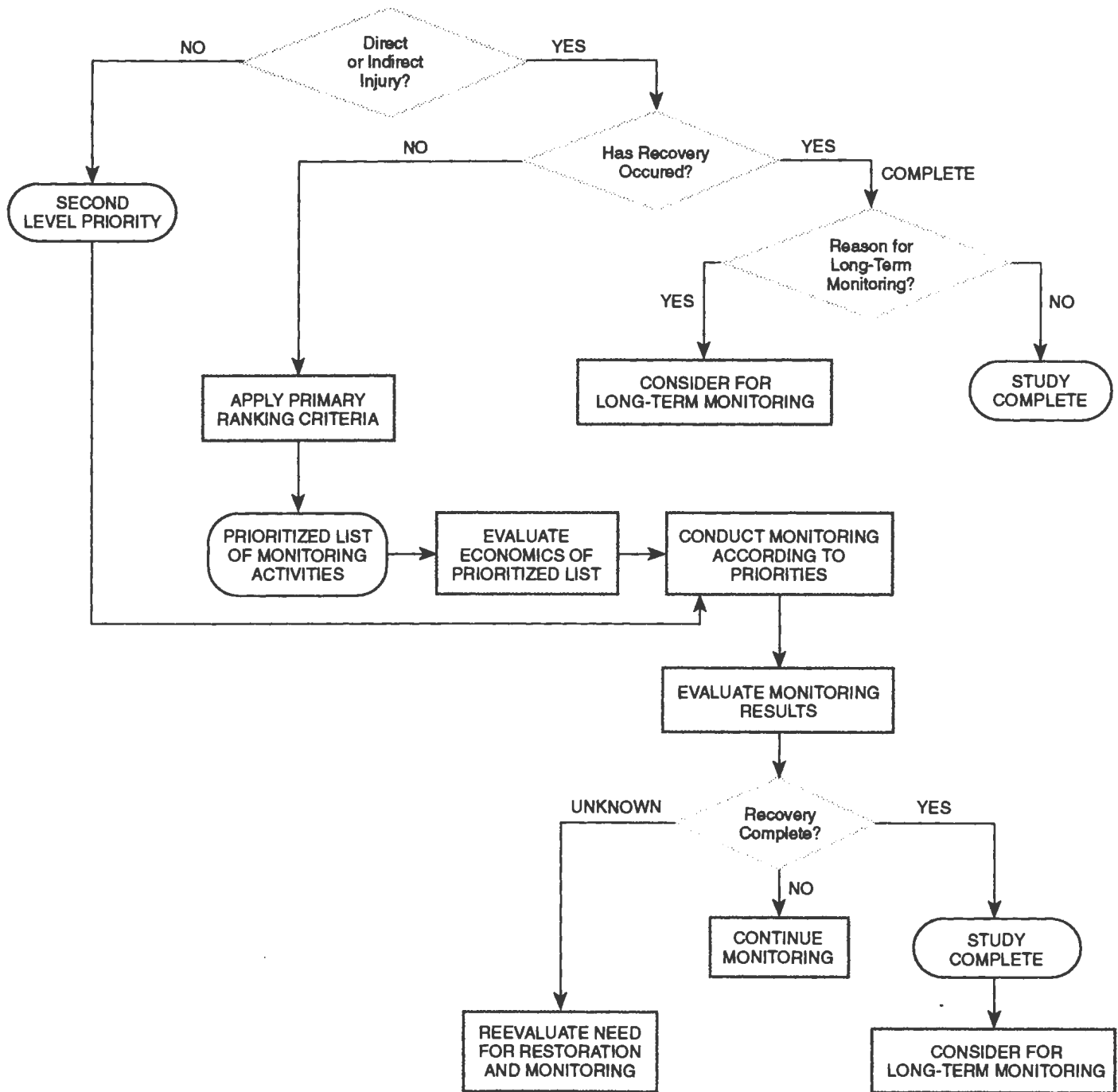
**Table 2. Criteria for evaluating resources and services for monitoring.**

**Primary Criteria**

- **Severity of Injury:**
  - Magnitude of injury
  - Is the injury continuing?
  - Evidence of recovery
  - Lack of pre-spill baseline
- **Ability to Monitor:**
  - Testable hypotheses
  - Restoration or compensation detectable, quantifiable
  - Quality of reference data (pre-spill or control)
  - Logistics (i.e., difficult, easy)
  - Quality of endpoint
  - Precision/accuracy (future monitoring)
- **Resource/Service Importance:**
  - Socioeconomic
  - Cultural/religious
  - Ecological

**Secondary Criteria**

- Contribution to understanding analogous resources and services
- Limited applicability to fishing and subsistence
- How non-destructive are sampling techniques?
- Regulatory restrictions inhibit monitoring
- How well are service characteristics and use dynamics understood?
- Sources of stress known/evaluated
- Ease of integration/coordination with other monitoring programs
- Provide data for the evaluation of future perturbations
- Resource/service monitoring not duplicated (at adequate precision/accuracy) by another agency
- Restoration or compensation is benefit to other injured resources or services
- Achievement of compensatory action (relates to services only)
  - Quantity (is it enough?)
  - Quality of action
  - Location of action
  - Perception of action



**Figure 4.**  
**Criteria Application Process**

information may not be highly valued. Thus, once the criteria are applied, the results should be compared to the costs—and potentially reordered to yield the most information for the money.

Finally, public feedback and scientific perspectives must be integrated. For example, if the public feels that monitoring killer whales is important, this activity must be compared to the monitoring priorities for other injured resources and services, to determine the relative benefits (both scientific and in public perception) of alternative monitoring activities.

In addition to prioritizing overall monitoring activities, it is necessary to set priorities for activities specific to a resource or service; this task is recommended for Phase 2. Priority should be given to activities that are most likely to address the needs and objectives of recovery monitoring. The criteria presented in Table 2 will be useful for this activity.

The criteria listed in Table 2 can be used as a planning and decision-making tool. As a planning tool, the criteria can be used by the Trustee Council to:

- Determine which of the injured resources and services identified to monitor.
- Develop specific requests for proposals for monitoring activities.
- Evaluate and rank proposals received in response to a request for proposals to monitor specific resources and/or services.

The criteria could also be used by respondents to a request for proposal, in their preparation of a monitoring proposal. Any proposed monitoring activity should consider each criterion.

As a decision-making tool, the criteria will be useful to the Trustee Council in deciding if a particular monitoring program is actually documenting recovery. If information, when compared to criteria, suggests that recovery is occurring or has occurred, the Trustee Council can make decisions to:

- Continue funding the program.
- Continue funding the program with altered sampling effort and/or over a different time scale.
- Discontinue funding.

If recovery is not occurring, the Trustee Council can use the criteria as a guide to:

- Evaluate the need to invest in restoration alternatives, or choose a different recovery endpoint(s).

- Evaluate the need to continue recovery monitoring but with a different focus.
- Decide if a feasibility study is necessary to determine why the resource or service is not recovering.

#### 4.3.4.1 Application of the Criteria

The workshop conducted during development of this plan included application of the criteria to the injured resources to establish monitoring priorities. All participants in the workshop recognized that the criteria are not perfect. However, this process yields a ranking of resources and services. Further refinement is recommended as discussed below.

The criteria are a series of statements related to the severity of injury, monitoring capability, and the importance of the resource or service (see Table 2). To allow prioritization of resources and services, the criteria are divided into primary and secondary criteria based on the general consensus of workshop participants. The primary criteria are the most important criteria, while secondary criteria provide additional information for refining the selection of resources and services to monitor, or monitoring activities to conduct. There are three primary criteria: (1) severity of injury, (2) ability to monitor, and (3) importance of the resource or service. Each of the primary criteria are broken into the subcriteria, listed in Table 2. For example, the subcriteria for *Severity of Injury* are *Magnitude of injury*, *Is the injury continuing?*, *Evidence of recovery*, and *Lack of pre-spill baseline information*. All of the subcriteria are important when determining the rank of the primary criterion *Severity of Injury*. In addition to primary criteria and their subcriteria, there are seven secondary criteria listed in Table 2. The secondary criteria allow more thorough evaluation of the resources and services, particularly if application of the primary criteria results in similar rankings for several resources and services.

For each criterion a high, medium or low ranking can be applied. The combined or mean rank of the subcriteria provide an overall rank of the primary criteria. To ensure that the ranking is applied in a consistent manner, definitions for each of the rankings must be provided. Possible definitions for the ranking of two criteria—magnitude of injury and socioeconomic importance—are presented below.

#### Magnitude of Injury

**High:** A high score (3) indicates there has been a population level or other direct effect to a resource or service grouping, (e.g., colony, pod, archeological site), and in more than a one geographic area, (e.g., the spill affected populations, regardless of geographic area, as opposed to affecting only the colony on Montague Island).

**Medium:** A medium score (2) indicates there has been a sublethal or less-than-population-level effect to a resource or service (i.e., one or only a few colonies or sites were

affected, but populations or services in most other areas either were not affected or are recovering).

**Low:** A low score (1) indicates that there has been a sublethal or indirect effect on the resource or service, or that a very limited population was affected and that the resource or service is already recovering.

#### **Socioeconomic Importance**

**High:** A high score (3) means that the resource or service is very important socioeconomically. For example, it provides the primary livelihood or food source for a local community.

**Medium:** A medium score (2) means that the resource or service has some socioeconomic value but that either it is of value only to small numbers of people, or its value is limited unless it can be grouped with other resources to form an overall high socioeconomic value.

**Low:** A low score (1) means that the resource or service has little or no known socioeconomic value. For example, the resource is not a significant food or pelt source, nor an important tourist resource.

The criteria presented on the matrix tables for resources and services are the same; however, some of the criteria may apply solely to specific resources or services. Ranking of various resources and services should involve consultation with experts in each resource and service to gain their technical insight and to determine the appropriateness of assigning ranks relative to other resources within a taxa or independently of each other. To obtain objective rankings, at least three experts should be asked to rank the resource or service using the criteria. Results from ranking conducted by experts at the workshop are presented in this conceptual plan (Table 3). However, the results are based on rankings by less than three experts for nearly all of the resources and services considered. These rankings need to be refined during Phase 2.

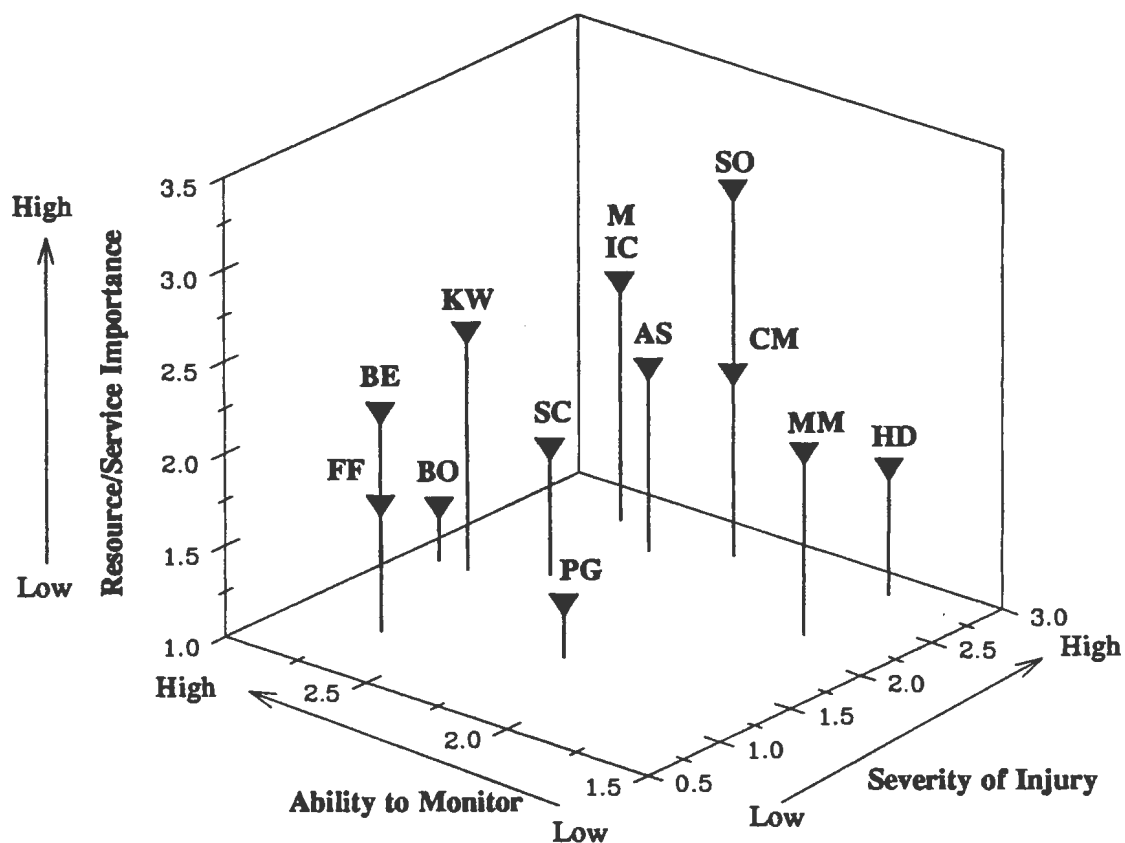
Application of the secondary criteria can clarify and/or supplement application of the primary criteria. Another ranking alternative is to convert the results to percentage responses, thus avoiding summation of the results. We do not recommend summing the scores over the entire range of criteria as this may result in a bias whereby a resource with a high total score may actually include several low-ranking criteria.

An example of how the criteria relate to selecting resources and services to monitor is illustrated in Table 3 and figures 5 and 6. Injured services may not be adequately represented by the broad categories, such as recreation and commercial tourism, therefore a matrix further defining the service categories was created (Table 4). Likewise, additional criteria apply to injured services, as indicated in Table 4. The number of service experts in attendance at the

**Table 3. Workshop example of application of criteria to the injured resources.**

CRITERIA	KILLER WHALE	SEA OTTER	HARBOR SEAL	RIVER OTTER	PIGEON GUILLEMOT	BLACK OYSTERCATCHER	COMMON MURRE	MARbled MURRELET	HARLEQUIN DUCK	CUTTTHROAT TROUT	DOLLY VARDEN	SOCKEYE SALMON	PACIFIC HERRING	ROCKFISH	PINK SALMON	ARCHEOLOGICAL SITES/ARTIFACTS	DESIGNATED WILDERNESS AREA	INTERTIDAL COMMUNITIES	SUBTIDAL COMMUNITIES	BALD EAGLE	MUSSELS	FORAGE FISH
<b>PRIMARY</b>																						
<b>Severity of Injury (Mean Score of Subcategories)</b>	1.8	2.7			1.3	1.8	2.7	2.2	2.8						2.5		2.7	2	1	2.7	1	
- Magnitude	2.8	3			1	1.5	3	2.5	2.5						2		3	2	1	2	1	
- Is the Injury Continuing?	1	2			1	2	3	2	3						3		3	2	1	3	1	
- Evidence of Recovery (3 = Low, 1 = High)	2	3			2	2	2	2	3						N/A		2	2	1	3		
<b>Ability to Monitor (Mean)</b>	2.8	2.3			2.2	2.9	2.3	1.8	1.8						2.5		2.7	2.6	2.7	2.7	2.7	
- Testable Hypotheses	3	3			2	3	3	2	2						3		3	3	3	3	3	
- Restoration Detectable, Quantifiable	3	2			2	3	3	2	2						3		3	3	3	3	3	
- Quality of Reference Data (Pre-spill or Control)	3	2			1.5	2.5	2	2	1.5						1		2	2	2	2	2	
- Logistics (1 = Difficult, 3 = Easy)	2	3			2.5	3	1	1	1.5						2		2	2	2	2	3	
- Quality of Endpoint	3	2			3	3	2	2	2						3		3	3	3	3	2	
- Precision/Accuracy (Future Monitoring)	3	2			2	3	3	2	2						3		3		3	3	3	
<b>Resource/Service Importance (Mean)</b>	2.3	3			1.3	1.3	2	2	1.7						2		2.3	1.7	2.2	2.3	1.7	
- Socioeconomic	3	3			1	1	3	3	2						1		3	1	2	3	1	
- Cultural/Religious	3	3			1	1	1	1	1						3		1	1	2.5	1	1	
- Ecological	1	3			2	2	2	2	2						2		3	3	2	3	3	
<b>SECONDARY</b>																						
Contribution to Understanding Analogous Resource/Service	1	1			1	1	2	2							2		3	3	2	1	3	
How Non-Destructive Are Sampling Techniques?	3	3			3	2	3	3							3		3	3	3	2	3	
Regulatory Restrictions Inhibit Monitoring (Many Restrictions = 1)	3	2			3	3	3	2	2						1		3	3	2	3	3	
How Well is Life History Understood?	2	3			2	2	3	1	1						1*		2	3	3	3	2	
Sources of Stress Known/Evaluated	2	1			2	2	2	3	1						1		2	2	2	2	1	
Ease of Integration/Coordination with Other Monitoring Programs	3	2			2	2	3	3	2						3		3	3	2	3	3	
Provide Data for the Evaluation of Future Perturbations	3	3			3	3	3	3	3						3		3	3		3	3	

\* "Life History" of Archeological Resources is seen as how much we currently know about the resources in the oil spill area.

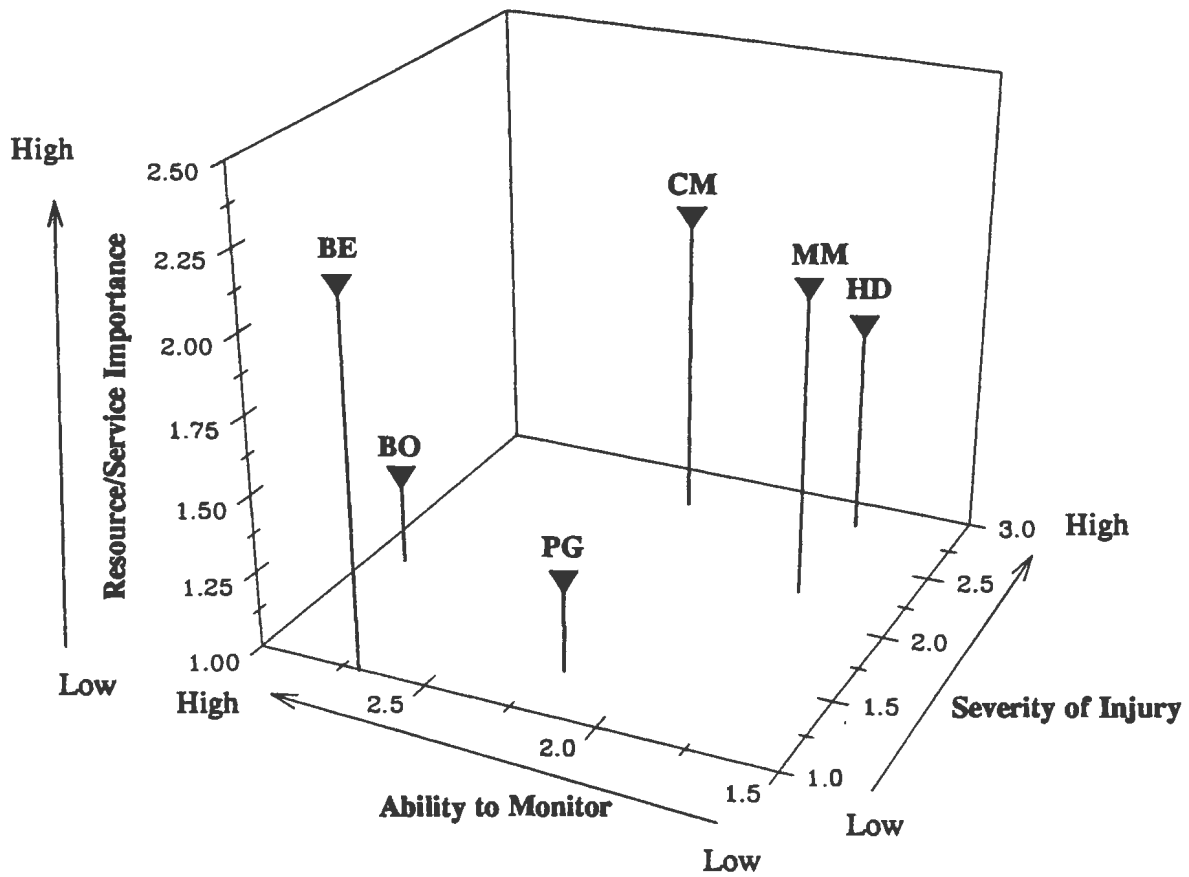


**Key to codes:**

- |                                  |                          |
|----------------------------------|--------------------------|
| AS= Archeological site/artifacts | KW= Killer whale         |
| BE= Bald eagle                   | M= Mussels               |
| BO= Black oystercatcher          | MM= Marbled murrelet     |
| CM= Common murre                 | PG= Pigeon guillemot     |
| FF= Forage fish                  | SC= Subtidal communities |
| HD= Harlequin duck               | SO= Sea otter            |
| IC= Intertidal communities       |                          |

**HIGH=** Greater importance, easier to sample, and greater severity of injury

**Figure 5.**  
**Three-Dimensional Graph**  
**Illustrating Results of Application of**  
**Primary Criteria to the Injured Resources**



**Key to codes:**

- BE= Bald eagle
- BO= Black oystercatcher
- CM= Common murre
- HD= Harlequin duck
- MM= Marbled murrelet
- PG= Pigeon guillemot
- HIGH= Greater importance,  
easier to sample and  
greater severity of injury

**Figure 6.**  
**Three-Dimensional Graph**  
**Illustrating Results of Application of**  
**Primary Criteria to the Injured Bird Species**





workshop did not provide the range of expertise needed to fully apply the criteria.

Figures 5 and 6 are examples of one type of presentation tool which illustrates the ranking of the primary criteria presented in Table 3. These three-dimensional diagrams may assist in interpreting the results of the ranking. Each axis in the figures is equally weighted and can be interpreted as follows: those resources and services that resulted in the highest mean for each axis (i.e., *resource or service importance* on the vertical axis, *ability to monitor* on the horizontal axis, and *severity of injury* on the axis providing depth) are given the highest priority for monitoring. Thus, resources and services that are closest to the back and uppermost point of the diagram are high priority. Not all injured resources and services are shown in Figure 4 because not all were ranked at the workshop. Results of application of the primary criteria follow:

First Priority:

- Mussels and intertidal community
- Sea otter
- Archeological sites/artifacts
- Common murre

Second Priority:

- Harlequin duck
- Marbled murrelet
- Subtidal community
- Killer whale

Third Priority:

- Black oystercatcher
- Bald eagle
- Forage fish
- Pigeon guillemot

If the Trustee Council decides that a broad range of resources are to be monitored, the resources can be divided into taxa groups, such as birds, mammals, fish and intertidal and subtidal communities. Reviewing the resources by taxa group, in this case birds, is exemplified in Figure 6 where the following priorities are indicated:

First Priority:	Common murre
Second Priority:	Harlequin duck and marbled murrelet
Third Priority:	Black oystercatcher, bald eagle and pigeon guillemot

Referring to the secondary criteria may be useful in decision making. For example, using Figure 6 (strictly the injured birds) and Table 2, it can be seen that the secondary criteria support the conclusion that common murrens should be a primary focus of monitoring.

Once criteria have been applied to prioritize the injured resources and services, requests for proposals can be developed for the higher priority resources and services. The criteria can also be applied, along with economic considerations, to evaluate proposals. Not all of the criteria would be applicable for evaluating proposals. For ranking proposals, the important criteria are: ability to monitor, resource importance, sampling techniques, integration/coordination with other monitoring programs and data for future perturbations. The proposals would be ranked as either high, medium, or low. All of the highest-ranked proposals would then be evaluated to determine any overlap between studies, identify opportunities for coordination between studies, and determine any linkages between the different proposed studies that will assist in understanding ecosystem recovery through trophic linkages.

Resources and services that do not receive a high rank during the first application of the criteria will not necessarily be eliminated from consideration for funding now or in the future. The prioritization process described above takes into account only technical aspects of monitoring. During Phase 2 of the monitoring program, the cost effectiveness of the proposal will be evaluated along with the technical criteria.

#### **4.3.4.2 Criteria for Evaluating Project and Long-Term Monitoring Priorities**

Additional criteria may be necessary or warranted for evaluating project and long-term monitoring. Criteria for long-term monitoring will assist the Trustee Council in determining when to continue monitoring beyond a defined recovery endpoint. Long-term monitoring may also include resources or services not identified by the Trustee Council as injured; it may also include chemical and physical parameters. The criteria developed for recovery monitoring may not be appropriate to apply to long-term monitoring.

#### **4.3.5 Linkages Between Resources and Services**

To facilitate review of linkages among resources and services, a matrix has been developed showing injured services and resources (Table 5). The matrix includes resources not directly affected by the spill but those which are linked to the resources and services that were affected (e.g., mussels and forage fish). The matrix also identifies relationships (both positive and negative, direct and indirect) between resources and services. It can be used as a tool to identify which recovery monitoring activities could be integrated and incorporated into a prioritization scheme, and where correlations exist. Input from resource and service experts should be sought to update the matrix periodically.

#### **4.3.6 Development of Conceptual Models**

Conceptual models help define cause-and-effect relationships, aid in the formulation of hypotheses, and assist in understanding the interactions among biological, physical, and chemical factors as well as anthropogenic influences (Figure 7). Conceptual modeling is the depiction of interactions of a resource or service with the factors affecting it.

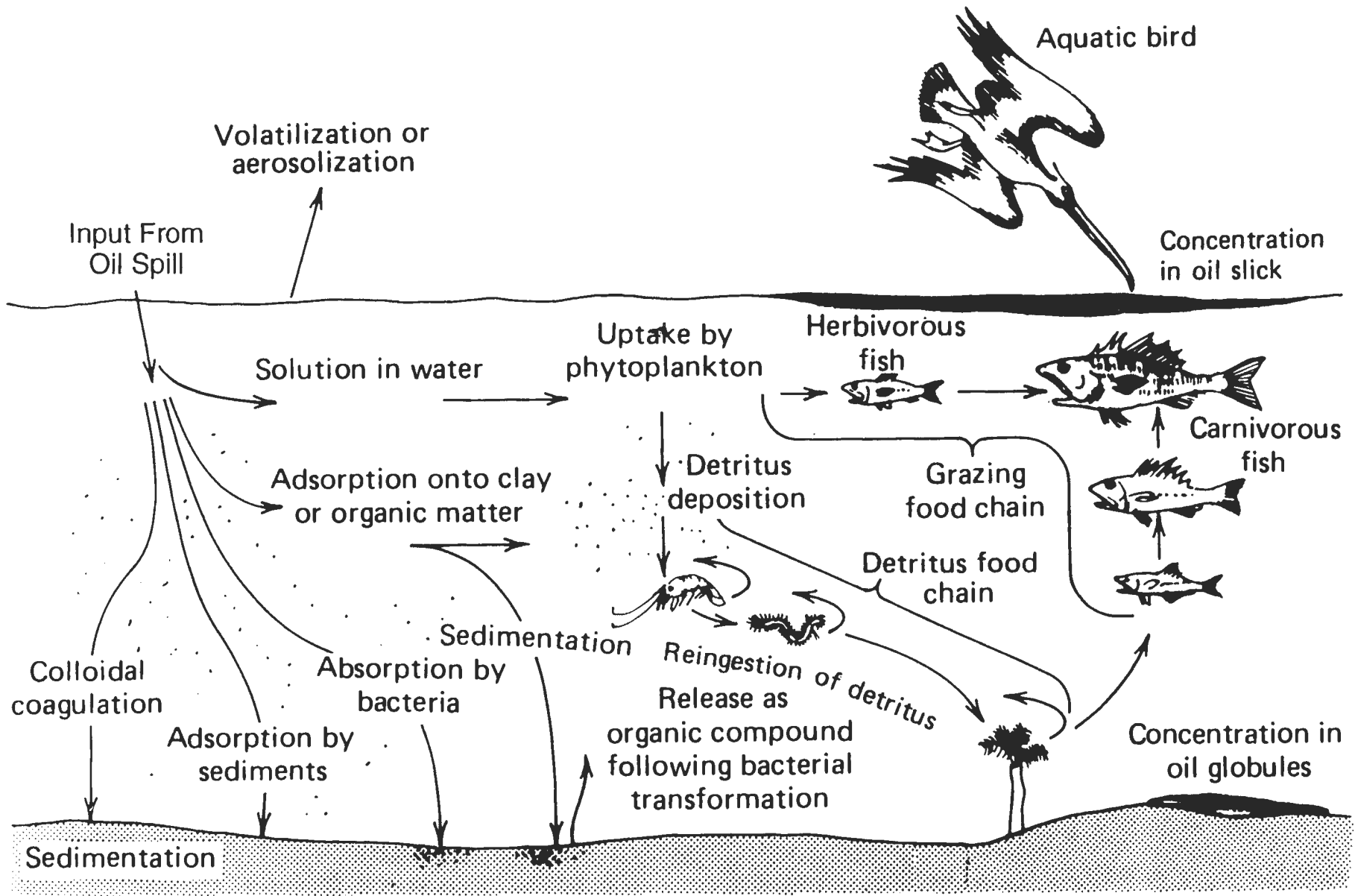
Conceptual models can draw upon diverse information, such as natural history, subjective judgment, ecological theory, and numerical models (NRC 1990). Information gathered through the NRDA, restoration activities, and from the literature, as well as planning activities (such as the workshop), can be factored into development of conceptual models for each resource and service. Identification of the needs, objectives and strategies of the monitoring plan, as identified in Section 3, should also be considered during development of the conceptual model(s) to ensure that the overall monitoring objectives are met.

As part of Phase 2 of the monitoring program, it is strongly recommended that conceptual models be developed for each resource and service. Figure 7 represents a conceptual model of the fate and transport of oil. This model could be further developed to address a specific resource or service. For example, a conceptual model for the black oystercatcher would include the intertidal and subtidal communities, bald eagles, mussels, sediment, water and tissue accumulation of hydrocarbons and the fate of hydrocarbons. The development of conceptual models can be completed by the contractor(s) for Phase 2, and/or as a requirement of the RFP.

#### **4.3.7 Other Methods for Setting Monitoring Priorities**

Adaptive Environmental Assessment (AEA) was another tool considered for setting priorities (Environment Canada 1982). Adaptive environmental assessment (AEA) is a technique developed by Dr. C.S. Holling (Holling 1978) that uses a variety of concepts and procedures for the design of resource management and policy alternatives. AEA incorporates environmental knowledge with social and economic concerns at the beginning of the design process. Because the systems being studied are dynamic, simulation and qualitative modeling, and policy design and evaluation are used. All of the user groups are involved and interact such that learning and problem solving are equally important. Those who must live under the policies of a given region have responsibility for the direction, design and understanding of the program, since they will be using it. Feedback mechanisms are built into the design.

AEA uses a workshop format to inform the various users about one other and to describe the status of information on the program to date, including information gaps. Workshops are used to prioritize activities to fill the information gaps using a mechanism that takes into account both scientific and policy views. It is not unusual for the AEA process to hold several workshops over the course a program. AEA also makes use of simulation models to establish links between the users and the information available.



Source: Adapted from Ecology, Impact Assessment, and Environmental Planning (1985).

Figure 7.  
Example Conceptual Model of  
Fate and Transport of Oil

Several of the principles of adaptive environmental assessment are elements contained in the mechanisms described in the conceptual monitoring plan. In development of this plan, and through Phase 2 and 3 of the monitoring program, it is expected that several elements of AEA will continue to be used.

## 5. GUIDANCE ON SAMPLING DESIGN

### 5.1 MONITORING PLAN PRINCIPLES

The goal of producing useful information for management decisions will only be achieved if the following basic principles are considered:

- Monitoring designs should reflect cause-effect relationships while accounting for variability and uncertainty.
- Specific design decisions (e.g., the number of stations, number of replicates, monitoring procedures) can be made only after objectives and related information needs are clearly established.

### 5.2 PRELIMINARY STUDIES

Critical to development of a successful sampling design is the development of testable hypotheses. The NRC (1990) identifies preliminary research as a key step in developing specific hypotheses. In the case of the *Exxon Valdez* oil spill, most of the preliminary studies were NRDA studies. The completed NRDA studies are generally adequate to fill the role of preliminary investigations for recovery monitoring, although not all have been completed or made available to users. In addition to the NRDA studies, other monitoring studies undertaken by resource agencies provide information that could serve as preliminary investigations. Conflicting results between preliminary studies and actual monitoring results should trigger a review mechanism to determine whether the difference in results is due to sampling design, methods of analysis, or changes in natural factors. If the difference in data cannot be readily explained, the results will need confirmation through continued monitoring. If results are confirmed, the study will then undergo the review process to determine its priority for continued monitoring.

### 5.3 SAMPLING DESIGN

As indicated above, a key component in the sampling design for specific studies is the link between questions and answers. Many of our nation's past monitoring studies have failed to meet expectations because they failed to link monitoring efforts to questions that can be answered. It is important that monitoring projects explicitly state what they intend to accomplish and that investigators be held accountable for accomplishing specific objectives.

The key elements identified by NRC (1990) for any monitoring activity include:

- Identification of meaningful types and magnitudes of change (e.g., time/spatial scales)
- Identification and quantification of sources of variability
- Specification of how variability will be partitioned

- Identification of what variables to measure
- Selection of statistical models appropriate for the type and number of variable(s)
- Optimization and power analyses to detect changes
- Identification of quality assurance objectives

Both users and investigators must define the types and levels of change that can be measured and how they will identify recovery of the resource and service. Likewise, natural variability must be a design consideration because seasonal, cyclic, and successional changes are major sources of variability that must be examined by investigators.

Variables selected for study should focus on those most likely to reflect recovery. Variables can include:

- Early warning indicators (those most likely to detect recovery)
- Sensitive indicators (those most sensitive to disturbance)
- Process indicators (those reflecting complex system interactions)
- High information indicators (those representing a number of different parameters or resources and/or services)

Statistical models that yield precise estimates with limited sampling effort should be selected. Variables should be selected that have high information-to-noise ratios adequate to test the identified hypotheses. The statistical models should define how questions and variability from other sources will be evaluated. For more information on statistical design refer to Appendix D. Sampling optimization and power analyses ensure that appropriate levels of effort are employed to meet objectives. These techniques require quantitative estimates of variability.

Quality assurance (QA) activities and quality control (QC) activities are vital for effective monitoring. Quality control plans should be included within individual monitoring plans to ensure standardization of sample collection, processing, analysis, and training. Quality assurance requirements should quantify the effectiveness of quality control procedures by instituting repetitive measurements, internal test samples, interchange of operators and equipment, independent verification of findings, and audits. The requirements should provide a means to correct or remove erroneous data and resolve inconsistencies that degrade data set integrity.

### 5.3.1 What to Measure

The focus of sampling should be on the resources and services injured by the spill. These resources provide opportunities to monitor ecological and biological variables as well as services provided by the resources. Monitoring activities could focus on investigations at differing levels of the food chain and on species that differ in migratory behavior, life span, and exposure to the original oil spill. These differences allow investigations of recovery over a wide range of parameters from the genetic integrity of populations to species abundance.



### 5.3.2 Where to Measure

Deciding where to measure resources also depends on the questions that have been asked. If the objective is to undertake long-term monitoring to compare with an existing pre-spill data set, it would be important to monitor in the same location and in the same manner as the previous work. If the question is how current conditions for the resources compare with conditions in undisturbed areas, there would need to be a set of parallel locations that differ primarily in their [potential] exposure to oil.

Where to measure would also depend on the species selected for study. For example, some marine mammals can be studied most effectively in their haul out areas, while others are more easily studied in foraging areas. Parallel studies might need to be considered for resources that use different habitats during portion of their life-cycle, for instance marbled murrelets and harlequin ducks.

### 5.3.3 How to Measure

Many measurement techniques are available, but technique selection depends on the questions being asked and the species being studied. If the objective is to duplicate previous data collection or dovetail with ongoing studies and monitoring programs, compatible techniques should be used, if possible.

The techniques selected must be appropriate for the species to be monitored. For example, aerial surveys may be appropriate for broad-scale censusing of marine mammals and seabird concentrations, but these surveys would not be suitable for species that are small and difficult to identify. For some species, different sampling methods would be necessary to characterize different aspects of their life cycle. Populations of resources in one geographic area might be accurately determined from boat surveys, but in other areas, sampling from the ground might provide better results. For example, boat surveys are needed to census foraging marbled murrelets, but ground surveys are necessary to locate possible nesting areas.

Population studies would require trapping and marking individuals. For studies on home ranges of biological resources (i.e., that address a habitat usage recovery endpoint), it might be necessary to use radio transmitters on individuals. In small home ranges, a portable radio receiver on the ground would be most useful. In large home ranges or for monitoring long-distance movements, it might be necessary to use helicopter- or airplane-mounted receivers.

For physiological studies or for toxicological analyses, it would be necessary to capture individuals. Some tests might be possible with samples collected in the field from animals that could be released. Other tests, such as trace elements analysis of organ tissues or electron microscopy of subcellular structures, would require the sacrifice of individuals. Special review and approval should be required for studies of this sort.

#### **5.3.4 When to Measure**

The timing of sampling will be determined by the monitoring parameters selected. Consideration must be given to conditions during the sampling period. For example, streams may be at high flow during a particular fish species' spawning period, rendering spawning counts difficult or impossible. Temporal coverage must also be adequate for the questions posed. For example, analysis of fish spawning populations or seabird nesting colonies may need to cover a long season to sufficiently enumerate all components of a population or area.

For physiological or toxicological studies, the sampling season is important because of changes that occur due to seasonal variability in food abundances, lipid content, and state of gonad maturation.

#### **5.3.5 Data Organization**

As is the case with other aspects of a sampling design, data organization depends on the questions being asked. It also depends on the analytical procedures to be used. Unless are compatible with prior data sets and with the overall monitoring database, it may be very difficult to use the data to answer the specific questions of a specific study. In those cases it would be most efficient to organize the data in a manner that provides the most usable results for the study.

In general, it is anticipated that data would be organized in a matrix format. The simplest format would be a two-dimensional matrix with columns representing independent and dependent variables and rows representing individual measurements. Typical independent and dependant variables would be time, location or condition descriptors, and environmental factors. The dependent variables could be any measurable factor that would help answer the initial questions posed and help determine if a recovery endpoint is reached. A three-dimensional matrix might be appropriate if similar, simultaneous studies are to be conducted on several species. Computational techniques allow the use of multi-dimensional data matrices, if that degree of complexity is appropriate to the initial questions.

#### **5.3.6 How to Analyze**

Data analysis is a key element of any sampling program, and it is essential to consider analysis when designing field data collection procedures. The analytical procedures must be focused on the basic question and on the recovery endpoint(s). The data collection must also be appropriate for the analytical procedures.

The nature of the data should be considered when determining the appropriate statistical methods. Normal variables are purely qualitative and cannot be assigned numerical values; thus, they may only be suitable for signs-based nonparametric or categorical statistical methods. Ordinal, or ranked, variables can be assigned numerical values, but the differences

among ranks are not necessarily proportional. These variables must be analyzed with nonparametric statistics. Many ecological measurements will be discrete variables. Discrete variables may be treated with parametric statistics, provided they satisfy the assumptions of those methods or can be transformed using a monotonic mathematical function. Categorical test methods may also be appropriate. Other environmental measurements are continuous, with no limits on possible values. Many physiological or toxicological measurements, such as metabolic rates or chemical concentrations, are continuous and can be analyzed with parametric statistics.

The particular statistical procedure to be used will depend on the nature of the questions being studied. For example, if the objective is to make comparisons between areas that were directly affected by the oil spill with other areas that were not affected, then a *t* test or analysis of variance might be appropriate. To demonstrate functional relationships, simple or multiple regression analysis could be useful.

### **5.3.7 How to Interpret**

If monitoring program objectives are clearly stated, specific questions addressed, and a comprehensive monitoring procedure implemented, then interpretation should be straightforward. The results of the analyses should directly answer the questions that are asked, and reasonable conclusions regarding the recovery endpoints should be drawn from the results.

Interpretation of the results of any particular study must be firmly based on reliable data that have been analyzed by statistically valid and relevant procedures. Any interpretation is only as rigorous as the weakest element in the entire data collection/analysis sequence. Care should be taken to avoid extrapolation to any interpretation beyond that which is justified by the available evidence and analysis.

If particular parameters are difficult to analyze statistically, more subjective interpretation of the data is necessary. In this case conclusions should be based on the preponderance of evidence rather than on individual results.

More detailed data interpretation may be necessary during hypothesis formulation for future monitoring activities. It is important to differentiate between data interpretation based on statistically valid results and speculation that may be conducted during hypotheses formulation.

## **5.4 USE OF EXISTING INFORMATION**

The design of monitoring elements should take into account methodologies developed to date. The methodologies employed in the NRDA and restoration studies may be applicable to the monitoring program. In particular, the sampling stations, parameters measured, and units of

measurements in these programs should be reviewed to optimize the information gained and to continue the collection of data for comparative reasons. This same strategy should be used when evaluating other, unrelated monitoring programs, so that the programs may be coordinated and/or integrated if appropriate.

The weaknesses and strengths of existing programs should be reviewed. The NRDA, restoration science studies, and other monitoring programs will provide examples pertinent to future studies.

Sampling guidance is provided below for the following taxa groups: avifauna and mammals, fish, intertidal and subtidal communities, and archeological resources. Guidance on monitoring services begins with Section 5.6, and covers each of the injured services.

## **5.5 GENERAL GUIDANCE ON SAMPLING RESOURCES**

General guidelines for monitoring specific resource categories are presented in four general categories: (1) avifauna and mammals, (2) fish, (3) intertidal and subtidal communities, and (4) archeological resources. Sampling designs specific to injured resources and services will need to be developed in Phase 2 of the monitoring program.

### **5.5.1 Avifauna and Mammals**

The focus of bird/mammal sampling should be on those species that were injured by the oil spill. The following elements should be considered in developing a sampling design:

- The monitoring program must be specific to the questions and recovery endpoints. For example, general questions on avian behavior may require censusing of large numbers of bird species and communities. Questions related to a specific food resource or foraging technique(s), may relate to a recovery endpoint associated with habitat usage or growth and may require that representative species be studied. For recovery endpoints related to reproductive success, surveys of breeding colonies and fledgling rates would be important. Toxicological questions requiring specimen analysis would place additional constraints on the selection of study species.
- Determine when and where a resource should be sampled. For example, some bird species can be studied most effectively in their breeding areas while others are more easily studied in foraging areas. For some seabird species that nest far from the marine environment, such as marbled murrelet or harlequin duck, parallel studies might need to be considered in nesting and foraging or wintering areas.
- Aerial surveys may be appropriate for broad-scale censusing of, for instance, seabird concentrations, but these surveys would not be suitable for species that are small and difficult to identify. Although aerial surveys would be inappropriate for small, widely

scattered populations, they could provide very accurate estimates of bald eagle breeding territories and nesting success.

- For some species, different sampling methods would be necessary to characterize different aspects of their life cycle. Populations of some seabird colonies might be accurately determined from boat surveys, but in other colonies, sampling from the ground might provide better results. For example, boat surveys are needed to census foraging marbled murrelets, but ground surveys are necessary to locate possible nesting areas.
- Multiple sampling periods during a breeding season may be appropriate for some species. For example, a preliminary aerial survey could locate active bald eagle nests, and a survey later in the breeding season could determine the success rate of active nests. For other species, separate surveys in separate locations may be necessary for breeding and wintering populations. For example, harlequin ducks will breed on interior rivers and spend the winter in the near-shore marine environment.
- The sampling season would also be important for some toxicological or physiological studies. Studies on hormonal changes related to breeding and reproduction recovery endpoints would have to be conducted over a time period spanning the breeding season. A study on trace element concentration in fat deposits would require sampling when body fat would be at maximum levels.

### **5.5.2 Fisheries**

Guidance on developing study designs to address fish species that were injured by the oil spill follows.

- Long-lived species, such as rockfish, may still show signs of spill-related impacts at either the population level (e.g., altered age structure) or individual level (e.g., physiological effects) and may be particularly valuable in assessing recovery.
- With the exception of rockfish, the target species migrate through many habitats during their life history. The questions posed in the monitoring program must be carefully tailored to the life history of the species, its niche in the aquatic community, the severity of the injury, and the recovery endpoint chosen for the resource.
- Each of the species noted provides direct services to humans, and monitoring of these services may be appropriate to assess recovery and/or identify harvest management actions that may be desirable to speed recovery.

- Due to the widespread distribution of the target species, it is important to focus the sampling efforts carefully to be certain of the level of exposure experienced by the population.
- The primary determinant of the sampling methodology will be whether monitoring of biological parameters or services, or both, is proposed. It may be possible to combine biological and service monitoring for the species because they are directly used by humans in subsistence, sport, or commercial fisheries. For example, tagging studies could be designed that provide vital population statistics and exploitation rates. This information may be useful both in assessing recovery and in formulating harvest management recommendations. For these types of studies, ongoing fisheries provide exceptional opportunities to use harvest efforts as tag-recapture efforts.
- Monitoring of salmonid spawner escapements may be desirable if the populations are under stress due to harvest or habitat degradation.
- Physiological or toxicological analysis may be appropriate on long-lived individuals that may still reflect exposure to the spill or to assess longer term changes in populations due to genetic effects.

### 5.5.3 Intertidal/subtidal

The organisms found in intertidal and subtidal habitats consist of those that live exclusively in the sediment, those that live exclusively in the water, and those that can make the transition between the water and the sediment. These organisms can range in size from minute to large, and all of these types of organisms constitute the entire biological assemblage found in a given area. Guidance on developing sampling designs to address these communities follows:

- In sampling intertidal or subtidal habitats, it is often logistically impossible or scientifically undesirable to sample for one specific taxon. Rather, the emphasis is on examining the components of the whole assemblage, community, or ecosystem.
- Monitoring should concentrate on the numerically dominant and ecologically important taxa. These taxa will need to be sampled so that predictions and analyses have sufficient statistical power to be meaningful. Several descriptive and derived quantitative ecological indices can be used to describe diversity and dominance of the faunal array from each station.
- If the questions involve comparisons of data collected over long-term sampling periods, then sampling should be in the same location as previous work. If the questions involve comparisons between current conditions in both spill and reference areas, then paired locations need to be chosen.

- The optimal sampling design is dependent upon which aspect (e.g., population size, growth, recruitment) of the benthos is studied and the habitat being examined. Similar sampling methods utilized in different habitats will sample different taxa. For example, the infauna of embayments open to the ocean will likely be very different from nearby areas of comparable sediments in fjords with a sill across the entrance (Shimek 1990). Regardless of the component of the benthos being examined, once the data are collected, much of the analysis is similar.
- No area to be sampled for the benthic assemblages can be assumed to be either spatially or bathymetrically homogeneous. Because of this potential variation, sampling should be at defined stations in the area. Based on preliminary analyses, the data from these stations may be shown to be statistically indistinguishable from station to station. If that is the case, those data may be pooled for subsequent analyses.
- Assemblages are often measured to discern changes among either the assemblages present at a reference or control area, or differences between the abundances in a sampled area and some pre-defined level of abundance that indicates recovery or restoration. When assessing assemblages of organisms, two measurable factors define many of the observed variations: diversity of the various taxa and abundance of those taxa.
- Annual monitoring will probably suffice for long-term monitoring programs. Nevertheless, seasonal, monthly, or even more frequent sampling periods may be necessary. For example, when questions of reproductive fitness are addressed, the need may exist for sampling gonadal indices over a longer period.
- The data collected from such sampling would be analyzed with the expressed intent of defining and describing the populations of the numerically dominant taxa. The abundant and, presumably, important or target taxa would be the focus of the analyses. Interpretation of the variations seen in these taxa will vary from project to project, depending upon the project design.
- Reference stations are chosen to provide indications of overall basin- or bay-wide changes, and are often used as a benchmark to assess normality of a study area. It should be recognized that it may be difficult or impossible to find true reference stations that are adequate for comparison to the *Exxon Valdez* recovery stations. Reference stations need to be chosen on the basis of sediment and hydrographic parameters to reflect "normal" or unstressed environments similar to that of the study area. Previous work has indicated that shallow-water unconsolidated reference areas may be difficult to identify.
- Rather than try to find a reference area for each of the habitats to be sampled, nearby stations may be chosen to provide "background" information about the basic trends in

the abundance and composition of the benthos. The background stations provide an indication of bay- or basin-wide changes in the fauna, although background stations are located in habitats similar to those being monitored.

#### **5.5.4 Archeological Resources**

Archeological resources are nonrenewable by natural or by human-assisted means. Unlike other resource components of the ecosystem, existing prehistoric and historic period sites cannot be replaced by natural processes. Archeological resources have a direct link to social, cultural, religious, and scientific values. Because these resources are nonrenewable and represent a link to the past and future, it is important to ask the following question: Will irretrievable loss (e.g., ethnic heritage value, cultural value) of some archeological sites and artifacts occur if some efforts are not undertaken to restore the injuries? Specific activities associated with archeological resources that should be considered in developing a monitoring sampling design include:

- Direct physical restoration of sites could occur for injuries caused by the oil spill response activities, looting, and vandalism. This activity does not meet the strict definition of recovery used in this conceptual plan, and may best be considered as a restoration activity.

Areas of surface disturbance at sites (e.g., looter holes, holes made during clean-up activities, ruts from vehicles) could be restored to reduce subsequent site disturbance (e.g., erosion, looting, and vandalism) which can occur if these areas are not restored. Refilling of holes can be accomplished using hand tools. Long-term monitoring of this type of restoration activity would not be necessary.

- Long-term monitoring could evaluate the occurrences and rates of vandalism at specific sites. Information from experts indicates that looting and vandalism resulted in the most significant impact to archeological resources.
- Long-term monitoring could be considered to evaluate the effects of oiling on sites, because the effect of oiling on chemical components of archeological sites and artifacts is not known.
- Damage assessment data indicate sites that should be considered for restoration actions and that should be considered in integrating archeological resources into the recovery monitoring program.
- As with other injured resources, a reasonable endpoint associated for archeological resources needs to be defined.



- Any "recovery," restoration, or long-term monitoring activities for archeological resources must be coordinated with the native groups, other users, and local governments, pursuant to the Archeological Resource Protection Act and the National Historic Preservation Act. Some native corporations require use of their services to access sites on their lands. Local governments should be asked to make recommendations for local sources of services at sites not on corporation lands.
- There are existing database systems for storing archeological data. However, archeological data (e.g., location of sites, site descriptions, maps) on federal, native, and state lands is kept confidential by law. Special contract language needs to be developed for activities associated with archeological resources to protect both the data and the integrity of the sites.

## 5.6 GENERAL GUIDANCE ON SAMPLING SERVICES

Several services were injured by the *Exxon Valdez* oil spill and should be considered for monitoring. Examples of direct-use services include hunting, fishing, hiking. Other services are related to passive or indirect uses (i.e., reading a book about the oil spill area or resources, viewing exhibits in a museum about a resource). Both direct- and indirect-use services can have a consumptive element (i.e., removing a resource) and a non-consumptive element (i.e., sightseeing).

Service-oriented monitoring programs should be integrated with monitoring studies on resource recovery. For example, a specific service-oriented study should be considered if a study is funded on recovery of the associated resource. Services, especially consumptive services, may affect recovery of a particular resource or affect linkages within the ecosystem. Therefore, it is important to understand how alleviating or changing the management of a particular service may affect resource recovery.

### 5.6.1 Recreation

Recreational services include activities such as sport fishing, sport hunting, boating, kayaking, and camping and hiking. Some of these activities (i.e., sport fishing) have a direct link to some of the injured resources (Table 5). However, the nature and extent of damages to recreational services varies by user group and area. Changes in use levels include potential users avoiding the spill area, users that note reduced wildlife sightings, and observations of residual oil. Changes in perceptions about recreational opportunities can also occur. Currently, there are indications that declines in recreational activities reported in 1989 did not continue in 1990. However there is also no evidence that activity levels have returned to pre-spill levels.

Factors to consider in sampling recreational services include:

Table 5. Matrix table of linkages between resources and services.

How Resource is Affected ↓	KILLER WHALE	SEA OTTER	HARBOR SEAL	RIVER OTTER	PIGEON GUILLEMOT	BLACK OYSTERCATCHER	COMMON MURRE	MARbled MURRELET	HARLEQUIN DUCK	BALD EAGLE	CUTTHROAT TROUT	DOLLY VARDEN	SOCKEYE SALMON	PINK SALMON	PACIFIC HERRING	ROCKFISH	ARCHEOLOGICAL SITES/ARTIFACTS	INTERTIDAL COMMUNITIES	SUBTIDAL COMMUNITIES	DESIGNATED WILDERNESS AREA	COMMERCIAL FISHING	COMMERCIAL TOURISM	PASSIVE USES	SUBSISTENCE	RECREATION	MUSSELS	FORAGE FISH	
Killer Whale	●	●											●	●	●				▲		○	○			△		●	
Sea Otter	○																	●	●		△	○		○	△	●	●	
Harbor Seal	○												●	●	●	●		●	●		○	○		○	△		●	
River Otter										●	●					●		●	●					○	△	●	●	
Pigeon Guillemot														●				●	●		△				△		●	
Black Oystercatcher										○								●	▲						△	●		
Common Murre										○									●		△	△			△		●	
Marbled Murrelet										○			●							●	△				△		●	
Harlequin Duck										○		(Roe) ●	● (Roe)					●	●	●	△			○	△	●		
Bald Eagle					●	●	●	●		●	●	●	●	●	●			●	●	●		△			△		●	
Cutthroat Trout				○						○															○		●	
Dolly Varden				○					(Roe) ○	○		●	●	●					●		○				○		●	
Sockeye Salmon	○	○						○	○	○		○		●				●	●		○	○		○	○	(Larvae) ●	●	
Pink Salmon	○	○						(Roe) ○	○	○		○			○			●	●		○	○		○	○		●	
Pacific Herring	○	○		○						○	○	○			○			●	●		○	○		○	○		●	
Rockfish		○	○											○ (Juv)				●	●		○	○			○		●	
Archeological Sites/Artifacts																					○	○			○			
Intertidal Communities		○	○	○	○	○			○	○			○	○	○	○						△			○	○	●	●
Subtidal Communities	△	○	○	○	○	△	○		○			○	○	○	○	○					○	△		○	△	●	●	
Designated Wilderness Areas								●	●	●												○			○			
Commercial Fishing	○	△	○	△	△		△	△	△	△	●	△	●	●	●	●				●		△		○			●	
Commercial Tourism	●	●	●				▲			●	●	●	●	●	●	●	●	▲		●	△				●		●	
Passive Uses	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●				●			
Subsistence		●	●	●				●					●	●	●				●	●		○					●	●
Recreation	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	▲	●	△	●			●	●	
Mussels		○	○	○	○				○									●	●					○	○			
Forage Fish	○	○	○	○	○		○	○		○	○	○	○	○	○	○		●	●		○			○	○			

○ Negative   ● Positive   ▲ Indirect   ● Direct

(Larvae)

- Recovery monitoring of recreational services should focus on the overlap between the different user groups and the injured resources. For example, if recovery monitoring of harlequin ducks indicates the species is recovering, sport hunting restrictions on the species may be eased, indicating a return or recovery of the sport hunting service.
- Native corporations need to be involved in recovery monitoring activities of recreational resources because they own significant land bases where recreation occurs, and they are major promoters of recreational activities.
- Recovery or restoration of recreational service is best determined by evaluating changes in use levels (e.g., angler days) and changes in users perceptions.
- Recovery endpoints of the specific recreational services need to be defined.

### 5.6.2 Subsistence

Subsistence resources provide food, resources, and products that are used in daily life and in cultural practices and traditions. They are also a means of providing a subsistence-cash economy.

Important factors to consider in planning and implementing a monitoring program for subsistence uses are listed below:

- A recovery endpoint needs to be defined. Recovery could be defined as having occurred when the community is harvesting resources (not necessarily the same resources) at a range comparable to pre-spill harvest rates. One approach to evaluating recovery is to evaluate existing harvest data to determine the natural range of variation for a subsistence harvest. The evaluation can then be used to identify the variation that will be considered an acceptable endpoint. A second approach for evaluating the recovery of subsistence harvests is to determine perceptions about contamination of food sources. A third approach, that could be integrated with either or both of the other approaches, is to integrate recovery monitoring activities of subsistence with specific subsistence resources.
- Involvement of subsistence communities in recovery monitoring allows the communities to take ownership in activities. For example, cooperative agreements could be established between subsistence communities, the Trustee Council, and an entity with expertise and experience in data collection and management. The communities could actually implement a recovery monitoring program as part of normal harvest activities with oversight by the organization with expertise.
- Subsistence communities could be selected for monitoring by (1) evaluating where documented changes have occurred and the extent of those changes, (2) identifying

representative communities in the oil spill area, and (3) selecting representative sites within those communities.

- Experts have suggested monitoring the following: levels of participation and shifts in harvest areas, contaminant levels, village-wide consumption levels, subsistence user perceptions, economic activity, and market assessments. Other parameters may be appropriate for monitoring.
- An appropriate method for implementing monitoring programs must be identified. For example, interviews are one method that can be used to qualitatively assess well-being. Interviews could occur initially at all representative sites within representative communities. This effort could be followed by a focused sampling effort.
- Include subsistence and fishing data (from other sources) in monitoring recovery of particular resources.

### **5.6.3 Commercial Tourism**

Commercial tourism is related to the passive use values discussed in Section 5.6.5. There are several types of commercial tourism (i.e., tour ships, day tours, and hunting and fishing charters) that need to be considered and evaluated for the recovery monitoring program. However, the endpoint is the same for each, a return to pre-spill levels of bookings and reservations.

Important factors to consider in planning and implementing monitoring activities for commercial tourist services are:

- Monitoring of tourism should focus on the overlap between the different user groups and the injured resources
- Consideration of the resources that draw tourists to Alaska
- An endpoint needs to be defined. One approach to defining a recovery level or an endpoint for tourism is to evaluate existing data to determine what the natural range of variation is for tourism and use that evaluation to identify the variation that will be considered an acceptable endpoint.
- Experts suggest monitoring the use of specific areas by tourists, numbers of tour boat visitors, and ferry passenger traffic.
- Economic experts indicate that the value (resulting net economic benefits) of monitoring a particular service needs to be evaluated by examining the links between the information obtained and population effects. For example, the net benefits of

monitoring the commercial salmon fishery could be measured by evaluating how the market would value a resulting change in fish populations and fishery practices.

#### **5.6.4 Commercial Fishing**

The commercial fishing industry is the second largest revenue generator in the state (EVOS Office 1993). Several of the injured resources identified in Section 4 support important commercial fisheries. Important factors to consider in planning and implementing a monitoring program for commercial fishing services include the following:

- Monitoring should focus on the overlap between the different user groups and the injured resources.
- A recovery endpoint needs to be defined. Recovery could be defined as the point when the commercial harvests are within a range comparable to pre-spill harvests. One approach is to evaluate existing catch data to determine the variation in harvests. This may define the acceptable endpoint.
- Commercial fisheries should be selected for monitoring based on documented changes in service and the extent of these changes, identifying representative fishing communities in the oil spill area, and selecting representative sites within the communities.
- Commercial fishing experts suggest monitoring fish mortality (from commercial as well as subsistence catches), the effects of hatchery production, escapement, economic activity in commercial fishing areas, and market assessments.
- Appropriate methods for implementing monitoring programs must be identified. For example, the fish ticket system provides an opportunity to evaluate the health of the fishery.

#### **5.6.5 Passive Uses**

Passive uses are related to recreational services and tourism and are represented by values that people place on a resource or habitat. Passive users can associate both use and non-use values to a resource. For example, a tourist visiting Pack Creek Bear Preserve may never visit or use McNeil River Preserve, but may value its existence. In addition, non-use values may be derived for a resource's existence, by a desire to pass resources on to the next generation, or intrinsically by deriving some value from the knowledge that the resource remains undisturbed. Passive use values could also be derived from knowing that there will be an option to use the resources in the future.

Passive use values include aesthetic, wilderness and intrinsic values. People generally place a high value on knowing that large undeveloped lands provide habitat for fish and wildlife and opportunities for aesthetic enjoyment and appreciation. Important factors to consider in planning and implementing a monitoring program for passive use services are:

- Monitoring of passive uses should be based on the overlap between the different user groups and the injured resources.
- As with other injured resources and services, an endpoint needs to be defined. Passive use recovery could be based on perceptions. One method is the application of contingent valuation. Based on information from the *Exxon Valdez Oil Spill Contingent Valuation* study (Hartman 1993 personal communication) it is technically feasible to value recovery monitoring activities and restoration activities of passive uses. The analysis could provide the Trustees with information on which recovery and restoration activities are most valued by the public. A limitation is that the valuation procedures would not be effective for defining the public perception of a recovery endpoint; it only yields information about the value of the recovery or restoration activity.
- Passive uses could be selected for monitoring by identifying the non-use values and attempting to quantify those values.
- Appropriate methods must be selected to evaluate these services. Surveys and interviews could be used to measure perceptions of recovery.

## 6. RELATIONSHIP TO OTHER MONITORING PROGRAMS

It is important that the recovery monitoring program be well coordinated both within and among programs. Monitoring activities for each of the monitoring types should be coordinated with one another, both in design and implementation. Additionally, recovery monitoring design should take advantage of information already generated through the damage assessment and restoration activities that have taken place since the spill, and whenever possible, should remain compatible with the earlier studies. In some cases this may include continuation of programs, and continued use of sampling sites, sampling stations, and sampling methodology. The recovery monitoring program should also be coordinated and/or integrated with other programs within the spill area and those that eventually may extend into the spill area.

Identifying monitoring programs within and outside the spill area is valuable for several reasons:

- Answers to some of the objectives of this monitoring program may already be planned or underway
- Other programs may provide information on methods, natural variation, and the usefulness of monitoring particular elements
- Dovetailing of programs may allow information to be generated on a more global level
- The monitoring in one program (e.g., effectiveness of restoration activity) may influence the results obtained in another program (e.g., natural recovery activity), through disturbance or enhancement of a site or population being studied.
- Lessons may be learned from the experience obtained in other programs.

Several programs may prove useful to coordinate and/or integrate with the spill monitoring program; many of these are listed in Table 6, a matrix for identifying common elements between monitoring programs. Monitoring parameters are listed down the left column. Monitoring programs that monitor these parameters are identified in the right column. For example, EPA's Environmental Mapping and Assessment Program (EMAP) monitors sediment chemistry and toxicity, sediment mixing depth, water column toxicity, tissue chemistry, submerged aquatic vegetation, benthos, pathology, and mussels. Some of these elements are specific to EMAP, and others are monitored by programs in addition to EMAP. Across the top of the table is the list of injured resources and services identified by the Trustee Council. This matrix can be used to identify other monitoring elements and programs with which the recovery monitoring may be coordinated. The table can be expanded to include each injured resource and service on the left column, and each monitoring program on

Table 6. Matrix of injured resources and services, and elements monitored by other programs.

Monitoring Element	Injured at Population Level (Direct Effects)										Injured But No Population Decline					Damaged Services					Monitoring Programs: <sup>1)</sup>						
	SEA OTTER	HARBOR SEAL	COMMON MURRE	MARBLED MURRELET	PIGION GUILLEMOT	HARLEQUIN DUCK	BLACK OYSTERCATCHER	SOCKEYE SALMON	WETLAND COMMUNITIES	SUBTIDAL COMMUNITIES	KILLER WHALE	RIVER OTTER	BALD EAGLE	CUTTHROAT TROUT	DOLLY VARDEN	PACIFIC HERRING	ROCKFISH	PINK SALMON	ARCHAEOLOGICAL SITES/ARTIFACTS	DEGRADED WILDLIFE AREA		COMMERCIAL FISHING	COMMERCIAL TOURISM	PASSIVE USERS	SUBSISTENCE	RECREATION	
Sediment Chemistry																										EMAP-Near Coastal, Chesapeake Bay Basin, PSAMP, NOAA S&T, Beaufort Sea, Cook Inlet RCAC, Great Lakes, Prince William Sound RCAC	
Sediment Toxicity (Bioassays)																											EMAP-Near Coastal, PSAMP
Biological Sediment Mixing Depth																											EMAP-Near Coastal
Water Chemistry																											EMAP-Near Coastal, National Surface Water Survey, Chesapeake Bay Basin, PSAMP, Great Lakes
Water Column Toxicity (Bioassays)																											EMAP - Near Coastal
Tissue Chemistry (Fish and Shellfish)																											EMAP-Near Coastal, Chesapeake Bay Basin, PSAMP, NOAA S&T, Cook Inlet RCAC, Great Lakes
Groundwater Chemistry																											Chesapeake Bay Basin, Great Lakes
Submerged Aquatic Vegetation																											EMAP-Near Coastal, Chesapeake Bay Basin, Beaufort Sea (reop)
Vegetation																											Chesapeake Bay Basin
Habitat Distribution/Condition																											PSAMP
Benthic: Abundance, Biomass, Species Composition																											EMAP-Near Coastal, Chesapeake Bay Basin, PSAMP, Cook Inlet RCAC, Great Lakes
Fish and/or Shellfish: Gross Pathology, Abundance, Species Composition																											EMAP-Near Coastal, Chesapeake Bay Basin, NOAA S&T, Beaufort Sea (fishery catch data), Cook Inlet RCAC, Great Lakes, NOAA (fisheries), ADF&G (fisheries)
Mussel Watch																											EMAP-Near Coastal, NOAA S&T, Beaufort Sea, Cook Inlet RCAC, Prince William Sound RCAC
Zooplankton																											Chesapeake Bay Basin, Great Lakes
Phytoplankton																											Chesapeake Bay Basin, Great Lakes
Bacteria																											Chesapeake Bay Basin
Birds: Water-Based																											Chesapeake Bay Basin, PSAMP, Beaufort Sea (oldsquaw, common eider), Great Lakes (comorants)
Reptiles, Amphibians																											Chesapeake Bay Basin
Mammal(s): Abundance, Tissue																											PSAMP, Beaufort Sea (bowhead whale, ringed seal), USFWS (seabirds, sea otter, boat bird surveys), NMFS (harbor seal, sea lion)
Methodologies to Learn From																											PSAMP, Chesapeake Bay Basin, Great Lakes, NOAA Status and Trends

<sup>1)</sup> Programs mentioned may not cover the same geographic area as the spill; however, if monitoring elements selected in the Exxon Valdez recovery monitoring overlap with those indicated here, information may be gained from review of methodologies.



the right column. This would allow, for example, an investigator monitoring the recovery of sea otters could use this matrix to determine that the U.S. Fish and Wildlife Service (USFWS) should be contacted to learn about the details and type of monitoring it does with sea otters.

## **6.1 RESOURCE AND SERVICE MONITORING PROGRAMS**

Resource and service monitoring programs that should be considered by the Trustee Council and the contractor(s) responsible for Phase 2 are listed and described below. A significant effort was made to contact knowledgeable individuals responsible for or working on these monitoring programs. Information for some monitoring programs is more specific than that provided for others. Contacts were not always available to answer questions. In addition, the scope and direction of these programs can change from year to year. Therefore, it is important that the Trustee Council routinely contact and coordinate with the contacts for these programs.

In addition to the programs identified below, additional damage assessments and restoration science programs should also be reviewed. This will ensure that methodologies are not reinvented and that data are collected in a format that allows the most comparability with the studies previously and/or currently being conducted.

### **6.1.1 Alaskan Monitoring Programs (State, Federal and Otherwise)**

- **Cook Inlet Regional Citizens Advisory Council (RCAC) monitoring program**

**Resource:** Sediment and tissue  
**Agency:** Cook Inlet RCAC  
Environmental Monitoring Committee  
**Contact:** Doug Coughenower  
**Phone:** (907) 235-5643

Monitoring is conducted in the vicinity of offshore terminal facilities and crude oil tankers operating in Cook Inlet. The program was initially a conceptual monitoring plan and a preliminary or pilot sampling scheme was developed. A modified (fewer stations sampled than originally planned) pilot program is currently underway (1993 field season). The RCAC will develop a work plan for subsequent years based on the 1993 results. Its goal is to secure funds for a long-term program or coordinate efforts with other programs.

The monitoring includes sampling the following for hydrocarbon analysis:

- National Oceanic and Atmospheric Administration (NOAA) mussel watch methodology for bivalves

- Benthic monitoring consisting of sediment chemistry, tissue chemistry, population studies
- Intertidal habitats sampling including tissue, sediment, and growth rates

For more information see also *A Comprehensive Monitoring Program for Cook Inlet, Alaska* Final Report October 1992. Prepared for Cook Inlet RCAC, Inc., Kenai, AK. Prepared by MBC Applied Environmental Sciences, Costa Mesa, CA.

- **Prince William Sound Regional Citizens Advisory Council (RCAC) monitoring program**

**Resources:** Sediment and tissue  
**Agency:** Prince William Sound RCAC  
**Contact:** Shelli Vacca  
**Phone:** (907) 277-7222

Program goals are to develop baseline data and, if possible, data to detect if there are any long-term effects from tankers and other boats. The monitoring began in late winter 1992/1993 with biannual surveys scheduled. The next survey is scheduled for summer 1993. The surveys cover nine locations in Prince William Sound, the Gulf of Alaska, the Kenai Peninsula, Kodiak Island and the Port of Valdez. The monitoring includes the collection of subtidal sediments and blue mussel tissue for measuring hydrocarbon concentrations and accumulation. NOAA mussel watch methodology is being used with transplants of caged mussels. The first report is currently undergoing peer review. An annual report will be available in December 1993.

The intent is for the monitoring to last as long as the pipeline is in use. Currently the program is funded through 1994.

See also *Final Project Plan Prince William Sound Regional Citizens Advisory Council Environmental Monitoring Program*. Hydrocarbon concentrations and accumulations in intertidal biota and nearshore sediments. Prepared for Prince William Sound RCAC Scientific Advisory Council, Anchorage, AK.

- **Alaska Department of Fish and Game (ADF&G) Programs**

**Resource:** Harbor seal surveys in Prince William Sound  
**Agency:** ADF&G  
**Contact:** Lloyd Laurey  
**Phone:** (907) 456-5156

Aerial surveys of east and central Prince William Sound are conducted in June and August-September, corresponding to pup and molt seasons. Aerial counts of 25 haul-out sites are conducted. Replicate counts are used to track trends in abundance. In 1990 time-depth recorders were employed that are linked via satellite and transmit daily information on the depth and length of dives. Monitoring has been ongoing since at least 1983 on a sporadic basis (1983, 1984, 1988, and 1989 through 1993). Seals were only monitored during the molt period in some years. Continuation of the monitoring depends on the funding available.

**Resource:** Harbor seal surveys  
**Agency:** Joint effort with ADF&G with National Oceanic and Atmospheric Administration (NOAA), National Marine Fisheries Service  
**Contact:** Tom Loughlin  
**Phone:** (206) 526-4045

Surveys to document trends in abundance, distribution and biomass (same as Prince William Sound effort) have been undertaken in Kodiak, Bristol Bay, and southeast Alaska since 1960. Studies cover pupping and molting using repetitive counts. Studies are conducted to learn about population declines.

**Resource:** Salmon escapement and mortality  
**Agency:** ADF&G  
**Contact:** Sam Sharr  
**Phone:** (907) 424-5900/424-3213

Studies include salmon escapement, and egg and fry mortality for pink salmon in Prince William Sound. Tag recovery is used to determine hatchery contribution to salmon populations. A restoration project is planned for 1994 to rehabilitate sockeye. By adding nutrients and reducing escapement into the lake, the existing wild stock of sockeye salmon will be rehabilitated.

**Resource:** Herring feeding, population and catch studies  
**Agency:** ADF&G  
**Contact:** Evelyn Biggs/John Wilcox  
**Phone:** (907) 424-3212

The program includes monitoring of spring catches of herring captured by five different types of commercial fishing gear including gillnets and purse seines. Surveys are also conducted in kelp spawn areas. Aerial surveys are flown from Cordova and cover the Prince William Sound area. Monitoring of herring is also conducted to collect data on sex and size classes, biomass, and smolt sites. In 1993 the Montague Island area is being monitored to collect age, sex, and size data.

**Resource/Service:** Commercial fish species  
**Agency:** ADF&G  
**Contact:** Scott Meyers and Bill Becthol  
**Phone:** (907) 267-2218 and (907) 235-8191).

ADF&G monitors commercial and sport fishery catches. Sport harvests have been monitored since 1991 in Prince William Sound; the Port of Valdez was monitored in 1992 only. The species composition of the harvest is monitored (percent of each species, age, sex, and size). Landings are checked five days a week from late May to early September (this equals approximately 90 percent of the harvest).

Commercial fishery harvests are also monitored (off Homer and Seward) for species composition; there have also been jigging and diving studies conducted on the south coast of Kenai. During 1989-1991 ADF&G also conducted studies at many sites in the spill area using diving and spearing techniques.

**Resource:** Rockfish  
**Agency:** ADF&G  
**Contact:** Andy Hoffman  
**Phone:** (907) 267-2238

ADF&G has conducted tissue sampling each year since the oil spill. The number of sampling sites and the extent of the tissue collection varied from year to year. In 1989 tissue samples were collected at 30 sites for hydrocarbon analysis. In 1990 only eight sites were sampled, four in Prince William Sound and four in lower Kenai. Two sites in each region were used as control sites. Histopathology and hydrocarbon analyses were performed on different tissues. Analyses were repeated in 1991 at four sites in Prince William Sound. The last sampling was conducted in 1991. The study was conducted as a result of the spill.

- **Oil Spill Health Task Force Group**

**Resource/Service:** Shellfish, Birds, Mammals and Fish/Subsistence  
**Agency:** Interagency - ADF&G contact  
**Contact:** Jim Fall  
**Phone:** (907) 267-2359

A task force was created to provide subsistence users with information about hydrocarbon contamination of resources. Hydrocarbon tests were performed on crab, clams, mussels, chitons, shrimp, birds (Barrow's and Goldeneye duck), seals, sea lions, salmon, and bottom fish. Hydrocarbon contamination was also assessed for commercial and sports users.

The interagency group includes the Indian Health Service, the Governor's Office, ADF&G, Alaska Department of Health and Social Services, Alaska Department of Environmental Conservation (ADEC), NOAA, North Pacific Rim Kodiak Area Native Association and Exxon. The last meeting was held approximately one year ago.

Harvest surveys were conducted at subsistence villages for three years. Villages with little impact were phased out of the survey over time. One hundred and forty-six survey sites for fish and shellfish were established, and animals were collected in the spring and summer between 1989 and 1990.

- **Oil Spill Response Institute proposed monitoring program**

**Resource:**      **Comprehensive**  
**Agency:**      Prince William Science Center  
                    Oil Spill and Response Institution  
**Contact:**      Dr. Gary Thomas  
**Phone:**         (907) 424-5800

The Oil Spill and Response Institute is planning to develop a long-term ambient monitoring program. This program will have three components: (1) conceptual, (2) implementation (including workshops), and (3) write up. The program will use mathematical models to link biological information to the ecology of the area. Estimates of caloric intake will be used to make estimates on populations using a bottom-up approach. Integration of optical and acoustical technology into the program is planned.

- **U.S. National Park Service intertidal and coastal programs**

**Resource/Service:** **Intertidal and coastal habitats**  
**Agency:**        U.S. National Park Service  
**Contact:**        Gail Irvine  
**Phone:**          (907) 257-2529

The intertidal and coastal habitat program is monitoring several resources including:

- Bald eagles (nesting surveys in 1992 at Kenai, Katmai, and Wrangle/St. Alias)
- Intertidal benthic algae, macrofauna, and invertebrates (counts and percent cover in rock substrates annually for two years)
- Harbor seals (a ground survey in Kenai in 1992, an aerial survey will be conducted by ADF&G)
- Stellar sea lions (population counts were done once in Katmai in 1992)
- Sea birds (counts over a one-week period)
- Sea and river otters (in Kenai)
- Harlequin ducks (in Prince William Sound)

- A multidisciplinary survey of intertidal habitats, birds, bears, archeological resources, and hydrocarbon and trace metals (in Cook Inlet)

Some study sites are in the oil spill area. Results will be assessed and the study may be redesigned to undertake long-term monitoring.

- **Coastal Marine Institute (affiliated with University of Alaska)**

**Resources:** Research and rehabilitation

**Agency:** City of Seward in collaboration with University of Alaska Institute for Marine Science

**Contact:** Seward Association for the Advancement of Marine Science

**Phone:** (907) 224-3080

This program is currently being developed. Its focus includes educational exhibits, research and rehabilitation. It is funded, at least in part, by the state criminal settlement funds from the spill.

There are several studies that have been initiated as a result of the *Exxon Valdez* oil spill. Some of these studies may be considered as monitoring programs. However, the continuation and/or extent of these studies may change over time. For example, some that do not currently emphasize recovery monitoring may change their emphasis to include recovery monitoring. Others may become components of routine ongoing monitoring programs. Examples of some of these programs are described below. Refer to *Exxon Valdez Oil Spill Restoration: Volume II 1992 Draft Work Plan, April 1992*.

- **Programs developed in response to the spill that are covered by the draft work plan (some of which are covered below)**

**Resource:** Archeological Sites

**Agency:** Alaska Department of Natural Resources (DNR)

**Contact:** Judy Bitner, Historic Preservation Officer

**Phone:** (907) 762-2626

The archaeological injury assessment was completed in 1991. It includes compilation of laboratory test results and artifact collections conducted from March to April 1992 to determine the direct oiling effects on historic and prehistoric site dating. A restoration program is planned for 1993 and will include erosion and vandalism studies at 24 damaged sites.

**Resource:** Migratory birds and sea otters  
**Agency:** U.S. Fish and Wildlife Service (USFWS)  
**Contact:** Karen Oakley, Vern Byrd and Jim Bodkin  
**Phone:** (907) 786-3579, (907) 235-6546 and (907) 786-3550

The program includes boat surveys conducted to determine the distribution and abundance of migratory birds and sea otters in Prince William Sound. Determining differences in bird and mammal abundances between oiled and clean areas, and determining changes in abundances following the spill are also included as part of the program. The program surveyed over 120 bird species including several that were identified as injured by the Trustee Council (e.g., harlequin duck, pigeon guillemot, marbled murrelets, and black oystercatcher). Twenty mammalian species were surveyed.

This program is ongoing in Prince William Sound and Cook Inlet.

**Resource:** Common murre  
**Agency:** U.S. Fish and Wildlife Service (USFWS)  
**Contact:** Vern Byrd  
**Phone:** (907) 235-6546

Population surveys of common murre and other seabird colonies were conducted in the spill area. It includes a comparison of pre- and post-spill numbers of breeding colony seabirds within the oil spill area and a comparison of reproductive chronology and productivity for murre. The surveys were initiated in 1989 and continue to the present.

**Resource:** Marbled murrelets  
**Agency:** USFWS  
**Contact:** Kathy Kuletz  
**Phone:** (907) 786-3453

An assessment of the abundance of marbled murrelet sites along the Kenai Peninsula and Prince William Sound was conducted. It includes comparison of populations surveyed in 1972—compared to those conducted in 1989 through 1991—and compiles data on deaths related directly to the *Exxon Valdez* oil spill. It also assesses those animals still living that suffered from petroleum hydrocarbon exposure.

**Resource:** Pigeon Guillemots  
**Agency:** USFWS  
**Contact:** Karen Oakley  
**Phone:** (907) 786-3579

An assessment of injury to waterbirds was conducted based on the population and breeding success of pigeon guillemots in Prince William Sound. The study goals included determining whether the total number of guillemots attending the colonies following the oil spill was significantly different than numbers prior to the spill; monitoring nesting success and chick growth rates; monitoring abundance and type of prey fed to chicks; determining whether petroleum hydrocarbons were present in adults, unhatched eggs, dead chicks, and prey items; and identifying potential restoration strategies. This program is ongoing.

**Resource:** Sediment and bivalves  
**Agency:** NOAA, National Marine Fisheries Service (NMFS)  
**Contact:** Ken Short  
**Phone:** (907) 789-6020

This program contrasted pre-spill and post-spill concentrations of hydrocarbons in sediments and mussels at intertidal sites in Prince William Sound and the Gulf of Alaska. Hydrocarbon data from ten historic and ten new sites established in Prince William Sound and on the Kenai Peninsula were analyzed and interpreted. Sampling also occurred after oiling to measure the change in hydrocarbon levels in sediments and mussels resulting from the spill. This study was conducted from 1989 to 1991.

**Resource:** Salmon/commercial fisheries  
**Agency:** ADF&G  
**Contact:** Sam Sharr  
**Phone:** (907) 424-3212

ADF&G monitors salmon escapement and egg and fry mortality for pink salmon in Prince William Sound. Coded wire tag recovery determines the contribution and any effects of hatchery fish on wild stocks. Spill injuries to salmon spawning areas were also studied to complete the data analysis from the damage assessment and restoration studies designed to improve the accuracy of wild pink salmon escapement estimates. Aerial surveys and stream life estimates were performed from 1990 to 1991.

Egg/pre-emergent fry sampling was completed to quantify effects of the spill on salmon eggs and fry. Increased egg mortality and a high incidence of somatic, cellular, and genetic abnormalities in alevins and fry from oiled streams were evaluated.

**Resource:** Archeological sites  
**Agency:** U.S. Forest Service (USFS)  
**Contact:** John Mattson  
**Phone:** (907) 271-2513



A study to determine the level of vandalism at ten USFS archaeological sites in Prince William Sound. The Chugach National Forest is the only vandalized site where chemical samples were collected and analyzed.

- **U.S. Fish and Wildlife Service Programs**

**Resource:** Sea otter  
**Agency:** USFWS  
**Contact:** Brenda Ballachey  
**Phone:** (907) 786-3417

This study measures the abundance and distribution of sea otters in Prince William Sound. It included monitoring the population demographics and habitat use in areas affected by *Exxon Valdez* oil spill. The USFWS is expecting to conduct aerial surveys in late July or August of 1993. In addition, it will investigate mortality patterns using beach surveys in winter.

Pre-spill monitoring data include results of population modeling and analyses. Non-spill-related monitoring includes an assessment of survival of young; use of radio transmitters at end of summer 1993; and bi-weekly monitoring.

A blood analysis (chemical and hematology) study was conducted in summer 1992.

**Resource:** Black oystercatcher  
**Agency:** USFWS  
**Contact:** Brad Andres  
**Phone:** (907) 786-3378

Black oystercatchers were monitored in central and east Prince William Sound. Studies included:

- Oil spill monitoring only
- Nest checks once weekly
- Tracking bird pairs to get fledgling success
- No baseline data
- Previous shoreline count in 1984 for breeding birds
- Monitoring in 1989, and 1991-1993

- **USFWS Environmental Studies Program**

**Resource:** Comprehensive  
**Agency:** USFWS  
**Contact:** Gail Irvine  
**Phone:** (907) 786-3550

Resources to be covered by this program and the extent of the program have yet to be finalized. Funding and implementation of the program are currently being determined. If the program is approved, surveys should begin in October 1993. Other potential participating agencies include the Minerals Management Service, Bureau of Land Management, and U.S. Coast Guard.

- **NOAA, Status and Trends/Mussel Watch/Benthic Surveillance program**

**Resources:** Bivalves and sediment  
**Agency:** NOAA  
**Contact:** Thomas O'Connor  
**Phone:** (301) 713-3028

Since 1984 this program has involved monitoring toxic organic compounds and trace metals (DDT, PCB, PAH, mercury and lead) in bottom-feeding fish, shellfish and surface sediments at 300 locations annually throughout the nation at fixed locations. The program examines relationships between exposures and indicators of biological responses in fish and shellfish (bioeffects) in areas with heavy contamination. Two monitoring sites currently under mussel watch are located in Alaska. These are Unakwit Inlet and Port Valdez. Twelve status and trends sampling sites are located in Alaska. (Note: The RCAC programs mentioned above are using NOAA Mussel Watch methodologies.)

- **NOAA, National Marine Fisheries Service Programs**

**Resource:** Fish Populations  
**Agency:** NOAA, NMFS  
**Contact:** Will vary depending on fishery stock of interest  
**Phone:** Not applicable

NMFS compiles an analysis of fisheries data to develop stock assessments. The principle information comes from the commercial and recreational harvests themselves. In addition, NMFS conducts resource surveys each year. Refer to *Our Living Oceans: Report on the Status of U.S. Living Marine Resources*; NOAA; December 1992.

The report includes a species-by-species descriptions of the status of Alaskan living marine resources that are assessed annually. The resources are grouped under six major headings: groundfish resources of the Bering Sea/Aleutian Islands region, groundfish resources of the Gulf of Alaska, pelagic resources, shellfish, salmon, and marine mammals. Elements monitored are population, biomass, mortality rates (natural, fishing), long-term and current potential yield. Some of the species reviewed are harbor seal, killer whale, and pink salmon. Refer to *Status of Living Marine Resources off Alaska as Assessed in 1991*; NOAA; November 1991.

**Resource:** Marine mammals  
**Agency:** NOAA, NMFS  
**Contact:** Marilyn Dalheim  
**Phone:** (206) 526-4045

Marine Mammal Protection Act project includes two aerial survey passes in the spill area in 1993 to record distribution and abundance of marine mammals.

**Resource:** Steller Sea Lions (Northern Sea Lions)  
**Agency:** NOAA, NMFS  
**Contact:** Tom Loughlin  
**Phone:** (206) 526-4045

This study provides aerial surveys (with ground surveys for verification) to monitor abundance and distribution of Steller sea lion pups in the Gulf of Alaska. This species is on the threatened list because its population is declining for unknown reasons. Surveys are conducted in late spring, early summer.

**Resource:** Killer whales  
**Agency:** NOAA, NMFS  
**Contact:** Marilyn Dalheim  
**Phone:** (206) 526-4045

An ongoing study of the pod injured by the spill includes photo identification of individuals in the pod. This is an ongoing monitoring activity funded by settlement monies.

**Resource:** Sediment and bivalves  
**Agency:** NOAA, NMFS, Auke Bay Laboratory  
**Contacts:** Drs. Jeep Rice, Larry Holmes, and Jeff Short  
**Phone:** (907) 789-6020

Post-spill monitoring of hydrocarbon concentrations has been conducted in sediment and tissue. Pre-spill monitoring in Prince William Sound from 1978-84 included mussel and sediment samples. Additional monitoring involves sampling oiled mussel beds from 1991 through 1994. This study includes survey of soft sediment and mussels, monitoring hydrocarbons at some sites outside Prince William Sound, and evaluation of methods of flushing hydrocarbons from mussel beds

**Resource:** Rockfish  
**Agency:** ADF&G in coordination with NOAA, NMFS  
**Contact:** Andy Hoffman  
**Phone:** (907) 267-2238

ADF&G and NMFS undertook a damage assessment study to look for the presence/absence of sublethal and lethal effects on rockfish within the spill area. In addition, rockfish were monitored by observers on trawl vessels for stock assessment on slope, pelagic and demersal rockfish populations. (See earlier description of NOAA, NMFS programs).

**Resource:** Intertidal and shallow subtidal  
**Agency:** NOAA, Auke Bay Laboratory  
**Contact:** Andy Hoffman  
**Phone:** (907) 267-2238

Richard Rosenthal conducted a life history, food habit, species composition and abundance studies on demersal species in Prince William Sound and southeast Alaska in the late 1970s and early 1980s. In Prince William Sound he conducted a shallow water fish community study. The southeast Alaska study included the continental shelf and was conducted through Bureau of Land Management and NOAA.

- **National Parks Management Council perch study**

**Resource:** Pacific ocean perch  
**Agency:** National Parks Management Council  
**Contact:** John Helfetz and Dave Clausen  
**Phone:** (907) 789-6000

Data dating back to 1977 were collected on Pacific ocean perch to assess the stock.

- **NOAA's National Undersea Research Program (NURP)**

**Resource:** Coastal ecosystem  
**Agency:** NOAA and University of Alaska, Fairbanks  
**Contact:** Ray Highsmith  
**Phone:** (907) 474-7836

The West Coast National Undersea Research Center (NURC) was established in 1990 as part of NURP. The Center's mission is to promote, facilitate and support undersea research along the west coast of the U.S. Research proposals include studies within the spill area. Program proposals are submitted by many different institutions and agencies including NMFS and ADF&G.

In 1992, through NURC, the National Marine Fisheries Services' Auke Bay Laboratory conducted a survey of the vertical distribution of Pacific ocean perch and spatial distribution of short-taker and roughey rockfish. NMFS' Kodiak laboratory conducted a study of aspects of mating aggregation of Tanner crab. The ADF&G conducted a depth distribution study of lingcod egg-masses in central southeast Alaska, and a depth and habitat distribution study of sea cucumbers.

- **NOAA weather service**

**Resource:** Meteorological  
**Agency:** NOAA Weather Service  
**Contact:** Ed Damin  
**Phone:** (907) 271-5131

Marine forecasts are made twice daily. Aviation forecasts are made for the entire state. There are 15 to 18 weather stations throughout the state. The weather service is also involved in measuring sea surface temperatures and conducting ice analyses for the arctic and Bering Sea.

- **U.S. Geologic Survey, Copper River - National Stream Quality Assessment**

**Resource:** Water quality  
**Agency:** U.S. Geologic Service (USGS)/Alaska Water Resources  
**Contact:** Bruce Bigalow  
**Phone:** (907) 786-7100 ext. 7125

Streams along the coast are being monitored, but no projects are related to the spill. USGS monitors 85 stations daily for water quality. Sixty-five flood peak stations, groundwater, and flood warning sites are monitored for daily flow, quantity and quality of flow.

This study had included sediment monitoring, but the funding ended two years ago. Formerly suspended solids were measured four times per year. The program has baseline data, including old sites in Prince William Sound area.

- **USGS Remote Sensing Program**

**Resource:** Not Applicable  
**Agency:** USGS (with National Stream Quality Assessment funds)  
**Contact:** Bruce Bigalow  
**Phone:** (907)786-7100 ext. 7125

Remote sensing is used to monitored at two sites within the oil spill area: Copper River (1988-1993) and Kodiak, mouth of the Terror River (since approximately 1981). These sites are monitored by satellite every four hours for minimum flow requirements.

- **National Surface Water Survey**

**Resource:** Water quality  
**Agency:** Environmental Protection Agency (EPA)  
**Contact:** Avis Newell  
**Phone:** (503) 754-4600

A one-time study to measure surface water chemistry in randomly selected lakes including Kenai. (See Report No. EPA/600/3-91/028 Nov. 1990)

- **Outer Continental Shelf Environmental Assessment Programs (OCSEAP) studies by the Department of Interior Outer Continental Shelf (OCS) and Minerals Management Service (MMS)**

**Resources:** Comprehensive, listed below  
**Agency:** MMS

The OCSEAP monitoring studies are generally related to oil and gas lease areas. Several elements may be monitored such as marine mammals, subsistence, seabirds, benthic communities. No known programs are underway in the spill area at this time.

- **Any programs developed with criminal settlement funds**

### **6.1.2 Private or Other Programs**

- **Sea World killer whale and humpback studies**

**Contact:** Marilyn Dahlheim  
**Phone:** (206) 526-4045

- **British Columbia killer whale monitoring program**

**Agency:** Vancouver Aquarium, British Columbia, Canada  
**Contact:** John Ford  
**Phone:** (604) 631-2507

An annual photo census has been conducted since 1973. Monitoring information has not been collected from the spill area. These surveys are a collaborative effort with the Canadian Department of Fisheries and Oceans.

- **U.S. Environmental Protection Agency's Environmental Mapping and Assessment Program (EMAP)—Near Coastal**

**Resources:** Sediment, Tissue, Intertidal and Subtidal Communities  
**Agency:** U.S. Environmental Protection Agency (USEPA)  
**Contact:** John Paul  
**Phone:** (401) 782-3037

EMAP includes the monitoring of sediment chemistry, sediment toxicity, biological sediment, water column toxicity, tissue chemistry, submerged aquatic vegetation, benthos (i.e., abundance, biomass, species composition), fish and/or shellfish (i.e., gross pathology, abundance, species composition) and mussels (i.e., mussel watch program). A two-tiered approach is used for sampling from a triangular point grid of the United States. The first tier will focus on gathering data through remote sensing, and the second on intensive data collection at sites selected to represent specific resources.

To date, Alaska has not been sampled but it will be as funding becomes available.

- **Global programs such as World Ocean Circulation Experiment (WOCE) and Tropical Ocean and Global Atmosphere (TOGA)**

**WOCE Contact:** Scientific Steering Committee, Paris, France  
**Phone:** 11-456-84042

**TOGA Contact:** Interworld Meteorological Association, Geneva, Switzerland  
**Phone:** 22-734-8234

- **Coastal Regional Monitoring Act/Program, Regional Marine Research (RMR) Program**

**Resource:** Coastal Ecosystem  
**Agency:** NOAA and EPA with SeaGrant  
**Contact:** Waldo Wakefield or Susan Sugai  
**Phone:** (907) 474-5870 or (907) 474-7086

The Regional Marine Research Act of 1991 established nine regional programs through the U.S. that all have federal oversight to set priorities for marine and coastal research to safeguard the water quality and ecosystem health, and carry out the research through grants and coordination efforts between programs. One of the nine regions is Alaska. Members of the Alaska board first met in September 1992 and held a workshop in March 1993 that included participation by 43 scientists and resource managers. This provided a focus and strategy for developing the comprehensive four-year plan that is required for each region. The plan will be submitted to NOAA/EPA in July 1993.

- **Joint Canadian, Russian, and USFWS program on seabirds**

**Resource:** Migratory seabirds  
**Agency:** USFWS  
**Contact:** Vern Byrd  
**Phone:** (907) 235-6546

A collaborative program between the U.S., Canada and the former Soviet Union has been developed to monitor seabirds. The intent of the program is to collect and archive data using USFWS methods and database structure.

### **6.1.3 Future Programs With Which to Coordinate**

- **NOAA Status and Trends program (previously described)**
- **U.S. National Park Service coastal program (previously described)**
- **U.S. Environmental Agency's (USEPA) Environmental Monitoring and Assessment Program (EMAP) - Near Coastal (previously described)**
- **U.S. National Park Service archeological program**

### **6.1.4 Monitoring Programs to Learn From**

- **U.S. Environmental Agency's (USEPA) Environmental Monitoring and Assessment Program (EMAP) - Near Coastal (previously described)**
- **Puget Sound Ambient Monitoring Program (PSAMP)**

**Resources:** Comprehensive, listed below  
**Agency:** Washington Department of Ecology  
**Contact:** Ken Dzinbal  
**Phone:** (206) 586-9031

PSAMP is a comprehensive, long-term monitoring program for measuring numerous aspects of the Puget Sound ecosystem that might be affected by pollution. The purpose of PSAMP is to characterize the condition of the water, sediment, plants, animals, and habitats in Puget Sound and its watersheds. PSAMP is intended to monitor ambient, or background, conditions in Puget Sound; this includes the cumulative effects of contamination and habitat degradation from many individual actions. PSAMP was developed to collect baseline and long-term information which will be used to detect long-term trends and changes in the Puget Sound environment.



Monitoring elements include:

- Sediment (chemistry and bioassay)
- Benthos
- Marine waters
- Fish and shellfish tissue
- Marine mammals tissue and abundance
- Birds abundance and harvest
- Nearshore habitat distribution
- Water quality parameters, resident fish tissue, and river mouth sediment for rivers and streams

- **Beaufort Environmental Monitoring Program**

**Resources:** Comprehensive, listed below

**Agency:** Canadian federal government, Department of Indian Affairs and Northern Development

**Contact:** Rick Hurst

**Phone:** (819) 994-7457

The monitoring program currently encompasses:

- Sediment chemistry
- Biological monitors/sentinel organisms
- Marine mammals
- Mussel watch
- Aerial transect surveys and behavioral data on the bowhead whales
- Anadromous fish; fishery catch data
- Densities of molting male oldsquaw
- Density and hatching success of nesting common eider
- Kelp community structure in the Boulder Patch
- Productivity
- Additional studies include ringed seals

- **Chesapeake Bay Basin Monitoring Program**

**Resources:** Comprehensive, listed below

**Agency:** EPA and cooperating federal, state and local agencies

**Contact:** Steve Gaber (Communications Office)

**Phone:** (410)267-0061 ext. 251

In 1987, the Chesapeake Bay Agreement made a commitment to reverse apparent declines in the quality and productivity of the Bay. Improvement and maintenance of water quality in the Bay were identified as the areas most critical to target. Nitrogen and phosphorus were targeted to be reduced by 40 percent between the 1985 baseline year and the year

2000. This trend analysis was initiated as a reevaluation of the 40 percent reduction goal and as part of the analysis of Chesapeake Bay water quality trends.

Monitoring occurs at a total of 49 mainstem stations. At the beginning of the program, stations were sampled twice monthly from March through October (summer schedule) and once a month from November through February (winter schedule). In 1988, sampling increased in some areas and decreased in others. Total nitrogen, total phosphorus and water quality (dissolved oxygen, temperature, conductivity, salinity and pH) parameters are measured.

Study elements include:

- Bacteriological
- Phytoplankton
- Zooplankton
- Benthos
- Submerged aquatic vegetation
- Vegetation
- Shellfish
- Finfish
- Waterfowl and other birds
- Reptiles and amphibians
- Chemical/physical component
- Water quality (mainstem, tidal tributaries, fall line, non-tidal tributaries and USGS stream flow, USGS groundwater, lakes, point and non-point source monitoring, habitat monitoring)
- Toxics monitoring (groundwater, sediment, shellfish tissue, finfish tissue)

See also *Chesapeake Bay Basin Monitoring Program*, Volume I: CBP/TRS 34/89 August 1989 and Volume II: CBP/TRS 35-89 August 1989.

• **Great Lakes Monitoring Program**

**Resources:** Comprehensive, listed below

**Agency:** EPA in cooperation with federal, state and local agencies

**Contact:** Bob Schacht/Wallace Matsunaga

**Phone:** (708) 531-5900

Studies elements include:

- Chemical data (groundwater, sediments, ambient water, biota)
- Invertebrates and Fish (phytoplankton, zooplankton, fish tissue)
- Biotic indicators (community structure, reproductive status of individual species)
- Reproductive status of sensitive species at the top of the food chain
- Reproduction and recruitment of lake trout and cormorants

See also *Strategic Great Lakes Monitoring Plan*, Draft April 1992; Great Lakes National Program Office; USEPA Chicago, IL.

- **Santa Monica Bay estuary/restoration program (Los Angeles Regional Water Control Board)**

**Resource:** Benthos and shellfish  
**Agency:** NOAA  
**Contact:** Al Mearns  
**Phone:** (206) 526-6941

The Bay Restoration Plan is structured into several categories to:

- Reduce sources of pollution (before entering the conveyance systems to the Bay)
- Reduce impacts on humans, marine life and habitats, and the ecosystems as a whole
- Restore, rehabilitate, and protect habitats, living resources, and biodiversity.

The program begins with benthic monitoring and expands, over time, to incorporate other monitoring, such as public health and seafood contamination. Finally, it adds storm drain, fish contamination, and others. Benthic monitoring is scheduled to begin May-September 1993.

## 6.2 SERVICE MONITORING PROGRAMS

The interview process identified two programs that contain elements useful to the monitoring program: (1) the subsistence monitoring by ADF&G, which included both the monitoring of shellfish tissue concentrations, and of consumption levels described above, and (2) the sport and commercial fish catch data collected by the state and USFWS. The usefulness of these or other surveys may change according to resource and service monitoring priorities. However both of the programs mentioned are the responsibility of resource management agencies; therefore, their continuation may not depend on spill settlement funds.

Additionally, surveys of perceptions (using key informant interviews and questionnaires) as well as evaluations of socioeconomic data associated with recovery of resources and services are useful. At least one such survey, a survey to assess the damages to services, has been performed by RPWG members.

- **U.S. Forest Service recreational use surveys**

**Service:** Recreation  
**Agency:** USFS

A survey was conducted to assess the intrinsic value of how people felt about recreation services in response to the oil spill. The data are currently being interpreted. Plans for future surveys are unknown at this time.

- **Mineral Management Services survey of subsistence use in coastal areas**

**Service:** Subsistence  
**Agency:** MMS, Department of Interior  
**Contact:** Joe Jorgensen (contractor)  
**Phone:** (714) 645-2471

A monitoring methodology was developed for the MMS to evaluate the potential impacts of oil and gas development activities and for inclusion into National Environmental Policy Act Environmental Impact Statements. The methodology is complex and involves using multiple data sets, matrices, and methods that specify variables that will serve as social indicators of other variables. In general, the monitoring program is a "longitudinal" study that attempts to determine the stability and reliability of conditions over time while recognizing a third parameter, reactivity (i.e., people talking to each other). This determination is made by asking panels of individuals empirical questions on economics, education, political activities, religious activities, and extracurricular activities using random sampling without replacement.

- **ADF&G subsistence survey and chemical contamination data**

**Service/Resource:** Subsistence/varies (see below)  
**Agency:** ADF&G  
**Contact:** Jim Fall  
**Phone:** (907) 267-2359

The state of Alaska conducted surveys prior to the spill, and in 1990, on the status of subsistence harvests and consumption. The results showed a decrease in harvests in some communities (Chenega, Tititlek). Warnings were issued by the State in 1989 for subsistence users to avoid consumption of intertidal invertebrates (mussels and clams) found along shorelines contaminated by oil. Chemical analyses of a wide spectrum of subsistence resources (fish, shellfish, ducks, marine mammals, deer) determined most resources, with the exception of some mussels and clams, to be safe for human consumption.

The study included surveys and chemical analyses of subsistence resources yearly from 1989 to 1991. They plan to continue sampling and analysis to document residue levels and restore the confidence in the safety of subsistence resources within the spill area. Future monitoring will include mussels, clams, rockfish, and bile and blubber from seals harvested in Prince William Sound.

- **ADF&G commercial fisheries (e.g., salmon escapement surveys and herring spawn deposition)**

**Resource:** Salmon/Herring  
**Agency:** ADF&G  
**Contact:** M.J. Mills  
**Phone:** (907) 267-2300

Since 1977 ADF&G has conducted an annual survey of anglers who sport fish in Alaska. The survey collected data on the number of fish harvested and the number of days fished. Since 1983 surveys have been site-specific for all areas of the state. Since 1984, ADF&G has also been collecting data on the number of anglers fishing each site and the number of household fishing trips to each site.

See also: *Alaska Sport Fishing in the Aftermath of the Exxon Valdez Oil Spill*; Special Publication No. 92-5; December 1992.

- **Restoration Planning Work Group survey of perceptions and use levels**

**Service:** Commercial Tourism  
**Agency:** RPWG  
**Contact:** McDowell Group  
**Phone:** (907) 278-8012

The McDowell Group and the Alaska Visitors Association have used business surveys and other research methods to identify injury from the spill. See also: *An Assessment of the Impact of the Exxon Valdez Oil Spill on The Alaska Tourism Industry*. Phase I: Initial Assessment. August 1990.

- **Oil Spill Health Task Force Group (described above under resources)**
- **Any programs developed with the criminal settlement funds**

Once the matrix table is completed, the linkages established, and a selection of monitoring parameters is made, contact should be made with each of the agencies/entities implementing the programs to provide an opportunity for integration and/or coordination. Independent experts should evaluate the methodologies used in the programs to determine their strengths and weaknesses. Any methodologies that prove suitable should be considered for incorporation into this monitoring program by maintaining and/or requiring comparability in methodologies, reporting units, length of monitoring, etc. Contact with these agencies/entities should be established both to coordinate activities and to ensure that the data are accessible to the Trustees' monitoring program.

## 7. MANAGEMENT OF MONITORING PROGRAM

### 7.1 MANAGEMENT STRATEGY

Implementing and managing the monitoring program will depend, to a large degree, on the availability of funds. The process used by the Trustee Council to implement and manage the monitoring program should result in a holistic approach to monitoring. The Trustee Council will need to consider some options about monitoring program oversight. One option is for the Trustee Council to select an independent contractor to manage and implement the program. A second option is for the Trustee Council to establish a Monitoring Management Committee (MMC). Management and implementation of the monitoring program should include a mechanism to ensure that monitoring activities are integrated and coordinated. The manager or management body must organize interactive teams at the start of monitoring efforts and assure that these teams consider the elements necessary to analyze recovery of resources and services of concern.

The first option, monitoring efforts managed by a single group, a contractor, or a team of contractors (a prime contractor with subcontractors), provides a mechanism for providing direct decision-making responsibility between the Trustee Council and the contractor. In addition, management responsibilities would also be centralized. The manager(s) would work with an advisory team that consists of the various user groups, including principal investigators, peer reviewers, the public, and agency staff, as well as RT members.

The second option is to use a system similar to that used by the Puget Sound Ambient Monitoring Program (PSAMP). Management would be conducted by a MMC made up of 15 to 30 individuals representing the various user groups. With the development of an MMC, an agency would most likely take the management and administrative lead. This option would result in a more diffuse decision-making responsibility, but may also provide greater involvement by user groups.

Under either option, public and peer review would occur prior to implementation (as further discussed below), with the final outcome of Phase 2 resulting in recommendations to the Trustee Council for implementation of the monitoring program (Phase 3). Management recommendations for Phase 3 might also stem from either management option, with the development of an institutional structure to coordinate and manage the program. Basically this consists of a steering committee formed of the agencies and institutions implementing the monitoring program. The advantage of this system is that the parties conducting the monitoring have an active role in managing it, and are presumably understanding, coordinating and using the results of the program.

Due to the political nature of the *Exxon Valdez* program, and the interest many agencies and institutions have in receiving settlement funds, we recommend that the Trustee Council use a single group rather than placing the responsibility with a management committee.

Program management includes not only the implementation of the program but also program reevaluation. It includes peer review and management of a database system. The most certain way to ensure that the data are collected, analyzed, and presented in a scientific and meaningful manner is for the management entity to provide objectivity to the selection and funding processes, while managing the projects within a set of requirements and guidelines. A competitive bid process is recommended, using peer reviewers from the proposal stage through the final award stage. The competitive bid process does not preclude agencies or organizations, rather it holds bidders to set standards, adds objectivity to the allocation of settlement funds, and provides a mechanism for achieving the best science.

Implementation of individual monitoring elements (Phase 3) for specific resources and services, or monitoring type could either be placed under one contract or under individual contracts to acquire the most appropriate expertise. However, all contractors should agree to comply with a set of guidelines (i.e., for QA/QC, schedule for deliverables) before being awarded a contract.

To meet the goals and objectives established in this conceptual monitoring plan, monitoring activities will require effective, well coordinated management. There are many competing interests for the settlement funds. There are also numerous competing objectives and goals outside those generally agreed to in the conceptual monitoring plan. Thus, well coordinated management is essential to leading monitoring activities in a manner that will attain the overall monitoring goal.

Several management tools that will help to ensure program effectiveness are stated below:

- Make decisions in a logical manner.
- Direct activities toward established goals.
- Involve interested parties in decisions.
- Make decisions on a timely basis.
- Communicate decisions immediately to the involved parties.

In addition to the tools mentioned above, the Trustees might benefit from the use of a program calendar or schedule. Detailed schedules with trigger dates should be developed for each of the project funding areas (i.e., monitoring, damage assessment, and restoration). These can then be overlaid to provide the Trustee Council with an overall restoration schedule which shows that activities are being directed toward established goals.

Feedback from the public, in the form of review by the Public Advisory Group, or public meetings on monitoring activities should be used by the Trustee Council to incorporate the priorities of the public in management of the monitoring program.

Information from principal investigators and peer reviewers can be used by the RT and Trustee Council to determine priorities and trigger points for scientific concerns. Principal investigators need substantial notice (months) to allow for securing logistical support. Therefore, their monitoring proposal must be reviewed and a funding decision made with at least several months' advance notice. Priority should be given to schedules that are calendar-driven or otherwise inflexible so as not to lose information.

Trigger dates may overlap between project areas or time lines that are impossible for the Trustee Council to meet. These should be negotiated at the onset of planning. In situations such as these, the Trustee Council should use outside expertise to prioritize and/or reschedule activities. If necessary the Council could delegate some responsibilities. The schedule discussed above should be continually revised and updated.

#### **7.1.1 Peer-Review Panel**

A peer-reviewer panel should be used to review all stages of program design and implementation. The reviewers should review and grade all proposed projects, following guidelines developed by the Trustee Council or using a format similar to that used by a well-accepted funding agency, such as the National Science Foundation (NSF). A similar peer-review process should be used for all project renewals and for review of draft and final reports.

The peer-review panel could be the existing panel or a new panel selected using lists of NSF reviewers. Reviewers could be chosen from the National Academy of Sciences, or by separate means. The panel should be relatively small, six to ten members, and should reflect all relevant expertise, including resource, monitoring, and quantitative experts as well as biostatisticians.

Since monitoring activities will continue for several years, it may be useful to have a rotating review panel. The first terms could be staggered (one to three years) so that all the peer reviewers would not be changed at the same time.

In addition, as part of the peer review panel a team of statisticians and modelers is recommended to review program designs. It would be especially useful if this team could act as a resource and be available to all projects teams. Acting in this as well as in the review capacity would ensure comparability of the programs. Biostatisticians could also be involved in proposal review and recommend upgrades or changes to a program.



The Trustee Council should specify strict time-frames for review and response by the peer-review panel. Lack of timely responses could severely hinder the entire program.

### **7.1.2 Funding**

A link between project approval and project funding should be established; a program designed to determine if recovery is occurring should not be curtailed due to a funding shortage part way through the program. Multiple-year contracts should be awarded to ensure that programs are funded for the period during which they are designed to document recovery, rather than intermittent funding or a yearly renewal. The project approval decision process needs to include steps for guaranteeing funding, with feedback mechanisms that still allow for project review.

A source of long-term funds can be ensured through establishment of an endowment. Cost estimates for program elements should be used to plan for the overall monitoring budget.

Though projects should be fully funded by the restoration funds, some monitoring activities may be able to be funded, in part, by outside sources—as long as use of outside funds is consistent with the monitoring program objectives. Matching or assisting funds might be available through an independent agency such as the NSF or the National Institutes of Health.

### **7.1.3 Data Management and Dissemination**

As the NRC stated, "Data management activities are as important to the success of monitoring programs as the collection of data" (NRC 1990). Through the organization, processing, and synthesis of data, together with knowledge, the data are endowed with reference and purpose, thereby becoming useful for decision making. Conversion of data to useful information involves planned data management, as well as planned data analysis in formats useful to the various user groups.

The goal of data management activities should be easy access to data and related information by all users, including resource and service managers. Because of the volume, complexity and interrelationships of data, it is essential to establish a computer-assisted data management system. All data should reside in a central repository or library, accessible by a computerized system linking the separate databases. At a minimum all data should be coded for retrieval by resource or service and geographic location. How and who can use this system will be a decision of the Trustee Council, but repository oversight should be the responsibility of the monitoring program manager.

It is important that the monitoring results be made public in a timely fashion, whether in the form of summary fact sheets, summaries of activities in the Restoration Plan, or in another form selected by the Trustee Council. Identification of data uses will help determine how the

information should be presented and disseminated. For example, if the Trustee Council develops work plans each year, it may want summaries of results or program status to present to the public.

Determination of the method for data dissemination to the different users is not a prime objective of the monitoring program; rather the objective is that results be integrated and the information be transferred in a format that can be readily used by scientists, resource managers, investigators and other interested parties. Mechanisms to disseminate data should be included in the monitoring proposals. The contracting process should enforce that data dissemination processes. Status reports should be included to allow evaluation and adjustments, where appropriate.

#### **7.1.4 Avoiding Duplication of Effort**

Integration and/or coordination with other programs is essential to avoid duplication of effort among studies funded with settlement monies, and those that are funded by other sources.

The following would facilitate the coordination between programs:

- Develop a table that identifies ongoing routine agency monitoring activities for resources and services affected by the oil spill or that occur within the oil spill area, as well as non-agency programs in the area or that may expand into the area. [Incorporating Geographic Information System (GIS) for maps may be useful for this purpose]. The information in Section 6 provides a start.
- Communicate with state and federal resource agencies to follow changes in routine agency monitoring activities.
- Communicate with non-agency programs to stay informed about changes in the programs that may influence the recovery monitoring.

It is assumed that some of the organizations currently conducting monitoring will submit proposals through the competitive bid process recommended herein. These organizations are well positioned to detect and avoid duplication of effort and should be encouraged to submit proposals.

## **7.2 REQUEST FOR PROPOSAL AND CONTRACT LANGUAGE**

Contracts should include incentives for completing tasks on schedule and penalties for tardiness to ensure timely performance. Incentives could include financial bonuses or some type of preferred status in selection for future work. Penalties could include the loss of money, or exclusion from consideration for further work. For example, standard contract

language could require the contractor to inform the client within a specified time frame that the contract cannot be met. The incentive in this case might be the avoidance of a penalty.

If the funding is from public sources, an additional means of encouraging timely performance might be a regular (biannual/annual) public review of project contracts. This could take the form of a public meeting where contractors present project status, schedule, and explain deviations. An alternative would be a regular display ad in local newspapers indicating similar types of information.

Several contract scenarios that use the basic ideas of incentives and penalties are described below. Depending on the details of the specific monitoring project, these approaches could be combined to include both incentives and penalties in the same contract. The following assumptions apply to each of the examples:

- Lump sum type contract
- \$100,000 total contract value
- \$20,000 mobilization costs

#### **7.2.1 Payment Tied to Deliverables/Schedule**

This form of contract would incorporate a number of deliverables such as reports or milestones in the monitoring process and payment would come after reaching milestones.

**Example:** If the project had four equal cost deliverables or milestones, the contractor would receive \$20,000 up front to get started. The next \$20,000 payment would be made upon completion of Task 1. Upon completion of Task 2, another \$20,000 would be paid. Thus, money is withheld until project completion (Task 4).

**Pros/cons:** This approach would work well with sequential tasks. The contractor would not have funds to work on Task 2 until Task 1 is successfully completed. This would protect the contractor as well as the funding source because the contractor's uncertainty over product acceptability is reduced.

This approach may not work well if the tasks are concurrent. In this case the contractor must commit all the effort up front, not knowing if approval will be granted for each milestone. If the contractor's representative is inexperienced or demanding, this type of contract may put the contractor at great risk.

This type of contract would not work well if the contractor is a public agency and needs total funding before beginning work. In this case, there would be no incentive to meet the schedule unless a penalty is included. A penalty, such as withholding the final 10 to 15 percent of the contract total until acceptance of the

final product, may be appropriate. In this case, a second penalty (e.g., exclusion from future work) may be necessary to provide adequate incentive.

### **7.2.2 Percent Reduction in Contract Total Value**

This model includes a penalty that reduces the total value of the contract relative to lack of timeliness. A percentage of the total value of the contract is established as a penalty and is withheld for each day/week the product is late.

Example: If the project has four equal cost deliverables, the contractor receives \$20,000 up front to get started. If the deliverable is one week late, and the penalty is calculated at one percent per week, then the penalty is \$1,000 ( $\$100,000 \cdot .1$ ). This penalty could be applied to a specific task (i.e. payment of \$19,000 for completion of Task 1), or it could be withheld from the last payment for Task 4. If the contractor was one week late on Task 1, met the schedule in Tasks 2 and 3, and was one week late on Task 4, the final payment would be \$18,000.

This approach could also include an incentive. If the milestone is reached early, a reward could provide money or another benefit to the contractor.

### **7.2.3 Incentive for Continuing Project Involvement**

This approach assumes that groups will desire long-term involvement with monitoring a specific resource or service.

Example: If a contractor successfully meets the deadlines/milestones in Year 1, they are automatically given first opportunity to do similar work in Year 2. If they miss a deadline, then the work in Year 2 is put out for competitive bid and the contractor runs the risk of losing the work. If the contractor decides to bid on Year 2 after losing automatic "rehire" rights, they will have to explain to the satisfaction of the Trustees their lack of performance in Year 1.

### **7.2.4 Schedule for Deliverables and Performance Criteria**

All contracts should specify performance criteria and a schedule. The performance criteria would pertain primarily to meeting QA/QC requirements, standard protocols, and data compatibility. An attachment to the contract document could specify protocols, QA/QC requirements, data format, and other performance criteria.

### **7.2.5 Proposal Ranking**

The Request for Proposals (RFP) should state evaluation criteria such as technical approach, statistical design, and cost. This will ensure that the proposals present the information necessary for review.

A copy of the contract with payment provisions could be included in the RFP. The contractor could be asked to comment on any potential problems with the contract format. This information could be helpful in determining the appropriateness of the selected contract format. This would be of particular value during the early portions of the monitoring program.

## 8. RECOMMENDATIONS

A summary of recommendations is presented below. Further elaboration on each recommendation is provided in individual sections of this document.

- The monitoring program and its results should be linked to the development of each year's annual work plan. Results of the monitoring program should be provided to the work plan work group with enough lead time so that the work group can use the results to plan for the upcoming year and field season.
- The Trustee Council should take advantage of existing, proven methodologies from damage assessment and restoration studies, and existing monitoring programs, to review monitoring activities. This will help ensure a successful program and provide the most comparable and long-term database for evaluation.
- This monitoring program should be coordinated or integrated with other monitoring programs, including resource agency programs. The matrix table of monitoring programs provided in Table 6 should be updated and expanded as needed for use in this manner. Contact with the programs identified should be made to explore the feasibility of integrating programs.
- All data should be centralized in a computerized library that is designed to meet the needs of the various users. The database should be managed by a single individual or organization.
- Continuous communication among the monitoring manager, principal investigators, and the Trustee Council is needed to ensure that program goals and objectives are being met. Continuous feedback is also needed between the Trustee Council and peer reviewers. This will ensure that the goals and objectives of the monitoring program and specific monitoring activities are being met. Peer review should be implemented at all stages of the program including proposals, sampling design, results, and final products.
- The Trustee Council should adopt (in Phase 2) the following approach to determine monitoring priorities:

*Involvement of user groups and consensus building.* Involve all user groups in the monitoring plan process, including the public, agencies, and scientists. Public involvement will ensure that the citizens' concerns regarding monitoring are identified and considered in finalizing and implementing the monitoring program. Involvement of resource and service experts will ensure establishment of a scientifically credible

program that provides useful information. Finally, involvement of all user groups will ensure that cross communication occurs between the various user groups.

*Development of goals, objectives, and strategies.* The goals, objectives, and strategies for the overall monitoring program are presented in this plan. Refinement of these goals, objectives, and strategies may be necessary once the Trustee Council adopts one of the monitoring alternatives presented in the draft Restoration Plan. In addition, goals, objectives, and strategies will be necessary for each monitoring activity for a resource or service.

*Review recovery endpoints and develop monitoring endpoints.* Recovery endpoints in this plan should be further reviewed by at least three experts on each resource and service. Recovery and monitoring endpoints not yet defined should be developed by resource and service experts. Endpoints are necessary and essential to construct testable hypotheses and develop conceptual models.

*Apply criteria to prioritize monitoring activities.* Injured resources with the direct (population level) and indirect (sublethal) effects are to be considered for monitoring. The resources and services that receive higher priority for monitoring should be those that are likely to yield the most meaningful information on recovery of the "ecosystem" affected by the *Exxon Valdez* oil spill. Monitoring priorities should be set through application of the criteria identified in this plan. Definition of the rank of each criterion for each resource and service needs to be further developed. Once the criteria are applied the results, along with costs for each monitoring element, can be considered. In addition, once the Trustee Council adopts the application of criteria as a mechanism for determining monitoring priorities, criteria can be developed to specifically address project and long-term monitoring.

*Develop and apply conceptual models to injured resources and services.* Conceptual models for each resource and service to be monitored need to be developed to better understand the biological, chemical and physical processes and interactions affecting the resource or service, as well as the social, cultural and economic factors. The development of conceptual models can be completed by the contractor(s) responsible for Phase 2, and/or as a requirement of a RFP and subsequent contract. Conceptual models will focus the monitoring on testable hypotheses, and assist in deciding monitoring priorities, specific monitoring strategies, and interpretation of results of the monitoring. The goals, objectives, and strategies as well as the linkage matrix and recovery endpoints contained herein can be used to develop conceptual models specific to resources and services.

- The conceptual issues outlined in this plan should be reviewed by the Trustee Council in formulating a RFP for Phase 2. The RFP should specifically state which issues the Trustee Council wants addressed and how.

- Monitoring elements outlined in Phase 2 should be awarded through a competitive bid process to ensure objectivity and to make the program as technically strong and credible as possible.
- Monitoring contracts should contain provisions to ensure that schedules, procedures, and QA/QC requirements are met. These provisions could include incentives, penalties. A combination of provisions can be considered.
- Guidelines for proposal preparation and contract award should be developed to standardize the quality of the deliverables received, ensure that information on the data collected will be archived in a computerized library of databases, and to facilitate use of the various databases generated.
- Projects awarded should be ensured funding throughout the time period necessary to document recovery, as long as the objectives of the monitoring program and requirements of the contract are met. Since the range of natural recovery is estimated to be between four and 120 years for the injured resources and services identified by the Trustee Council, an endowment for long-term funding will be necessary and is recommended to support these efforts.
- Phase 3 of the monitoring program (implementation) should be managed by an independent group, contractor, or agency that does not have political or monetary interests in the direction of the program. The independent manager(s) should have access to an advisory group of representatives from the user groups and access to all principal investigators.



## 9. REFERENCES

- Chan, G. L. 1977. The five-year recruitment of marine life after the 1971 San Francisco oil spill. Proceedings of the International Oil Spill Conference. American Petroleum Institute. 549-558.
- Conan, G. 1982. The long-term effects of the *Amoco Cadiz* oil spill. Phil. Trans. R. Soc. Lond. 297:323-333.
- Cretney, W. J., C. S. Wong, D. R. Green, and C. A. Bawden. 1978. Long-term fate of a heavy oil in a spill-contaminated B. C. coastal bay. J. Fish. Res. Board Can. 35:521-527.
- Elmgren, R., S. Hansson, U. Larsson, B. Sundelin, and P. D. Boehm. 1983. The *Tsesis* oil spill: acute and long-term impact on the benthos. Marine Biology. 73:51-65.
- Environment Canada. 1982. Review and Evaluation of Adaptive Environmental Assessment and Management. Prepared by ESSA Environmental and Social Systems Analysts Ltd. Vancouver, British Columbia, Canada. 116p.
- Exxon Valdez* Oil Spill Restoration Office (EVOS Office). 1993. Draft *Exxon Valdez* oil spill restoration plan: summary of alternatives for public comment. Prepared for public comment by the *Exxon Valdez* Oil Spill Trustee Council. Anchorage, Alaska.
- Green, R.H. 1979. Sampling Design and Statistical Methods for Environmental Biologists. John Wiley & Sons. New York, N.Y. 257p.
- Hartman, J. 1993. Personal communication of April 13, 1993. Economist, Alaska Department of Fish and Game, Juneau, Alaska.
- Holling, C.S. ed. 1978. Adaptive Environmental Assessment and Management. John Wiley and Sons. 116 pp.
- Linden, O., R. Elmgren, and P. Boehm. 1979. The *Tsesis* oil spill: its impact on the coastal ecosystem of the Baltic Sea. *Ambio* 8:244-253.
- National Research Council (NRC). 1990. Managing Troubled Waters: The Role of Marine Environmental Monitoring. National Academy Press. Washington, D.C. 125p.
- Shimek, R. L. 1990. Diet and habitat utilization in a Northeastern Pacific Ocean scaphopod assemblage. American Malacological Bulletin. 7:147-169.
- Teal, J. M. and R. W. Howarth. 1984. Oil spill studies: a review of ecological effects. Environmental Management 8:27-44.

**APPENDIX A**

**QUESTIONNAIRES FOR DEVELOPMENT OF PRELIMINARY DRAFT OF  
CONCEPTUAL PLAN**

**Questionnaire No. 1**

**QUESTIONS FOR INTERVIEWS WITH "EXPERTS"**

1. What are your expectations of the monitoring program?
  - of the conceptual plan?
  
2. What do you think the focus of the monitoring program should be?
  - what do you want to achieve?
  - what are your concerns?
  - are there any regulatory requirements you are aware of?
  
3. What do you believe are the primary goals of the monitoring?
  
4. How would you determine if recovery is adequate?
  
5. Do you have an opinion on the resources and services that should be monitored?
  - any prioritization?
  - why do you believe these resources/services are important?
  
6. What regional monitoring programs should this monitoring program be integrated with?
  
7. How best do you believe the data can be used as decision-making tools?
  
8. Is there anything important to the conceptual monitoring plan that we have not asked you about?

## QUESTIONNAIRE NO. 2

### QUESTIONS FOR INTERVIEWS WITH EXPERTS

1. What do you think a conceptual monitoring plan should accomplish?

#### Objectives

2. After reviewing the list of objectives which, if any, should be changed and are there other objectives we should consider?

#### Strategies

3. After reviewing the list of strategies which, if any, should be changed and are there other strategies we should consider?

#### Criteria

4. Can you tell us how you think the stated criteria should help direct the decision making process for restoration monitoring?
5. Is there other information or questions that we should consider as criteria for decision making in defining restoration monitoring activities?
6. What, if any, priorities or weightings would you give to the listed criteria as part of an objective decision making process?
7. What criteria are the most useful or least useful given your area of expertise?

## Other Questions

8. Are there special innovative forms of statistical design and analysis which you are currently involved with that may apply to a given resource or service?
  
9. What kinds of qualitative analyses, if any, should be applied effectively to a monitoring program if a resource or service is not amenable to a quantitative analysis?
  
10. What damage assessment databases are you aware of that we should consider?

What are the strengths/weaknesses of these databases?

11. What characteristics do you think are most important in developing an integrated database?
  
12. What if any monitoring programs that you are aware of do you think the restoration monitoring should be coordinated with?
  
13. How would you recommend incorporating services into this conceptual monitoring plan?

14. Are you familiar with specific survey instruments which effectively assess impacts/restoration on injured services like recreation, subsistence, aesthetics, etc.? If so, are there any kinds of qualitative data collection that can be of use to this monitoring plan?
  
15. Which surveys of services (e.g., recreation, subsistence, aesthetics) provided by natural resources contain elements that would best serve the purposes of the conceptual monitoring plan?

What are these elements?

16. Is there anything else that you think is important to include in the conceptual monitoring plan that you would like to comment on?

**LIST OF INTERVIEW PARTICIPANTS**

**APPENDIX B**

**INDIVIDUALS PARTICIPATING IN INTERVIEWS**

<b>RESOURCE SERVICE REPRESENTED</b>	<b>CONTACT</b>	<b>RESTORATION TEAM</b>	<b>RESTORATION PLANNING WORK GROUP</b>	<b>PEER REVIEWER</b>	<b>PRINCIPAL INVESTIGATOR</b>
<b>OVERVIEW, MARINE ECOLOGY</b>					
	Bob Spies, PhD			X	
	Don Boesch, PhD			X	
	Pete Peterson, PhD			X	
	Gail Irvine, PhD				X
	Bruce Wright			X	
	Doug Wolfe, PhD			X	
subtidal communities	Stan Rice, PhD			X	
coastal communities	Ray Highsmith, PhD				X
benthic communities	Steven Jewett, PhD				X
	Al Mearns, PhD				X
<b>MARINE MAMMALS</b>					
pinnipeds	Don Siniff, PhD			X	
killer whales	John Ford, PhD			X	
sea otters	Jim Bodkin				X
river otters	Jim Faro				X
humpback whale/killer whales	Marilyn Dahlheim, PhD				X
harbor seals	Kathy Frost				X



RESOURCE SERVICE REPRESENTED	CONTACT	RESTORATION TEAM	RESTORATION PLANNING WORK GROUP	PEER REVIEWER	PRINCIPAL INVESTIGATOR
<b>FISHERIES</b>					
	Ray Hilborn			X	
salmon	Phil Mundy, PhD			X	
	Joe Sullivan, PhD				X
pink/chum salmon	Sam Sharr				X
sockeye salmon	Dana Schmidt				X
<b>BIRDS</b>					
seabirds	Vern Byrd - <i>also river otters</i>				X
seabirds	George Hunt, PhD			X	
sea ducks	Sam Patten, PhD				X
bird restoration	Dennis Heineman, PhD			X	
bird toxicology	Michael Fry, PhD			X	
<b>ARCHEOLOGY</b>					
	Martin McAllister, PhD			X	
	Doug Reger				X
<b>RECREATION</b>					
	Jim Richardson			X	
	Jon Isaacs			X	

RESOURCE SERVICE REPRESENTED	CONTACT	RESTORATION TEAM	RESTORATION PLANNING WORK GROUP	PEER REVIEWER	PRINCIPAL INVESTIGATOR
SUBSISTENCE					
	Jim Fall, PhD				X
RESOURCE ECONOMICS					
commercial fisheries	Lewis Queirolo, PhD				X
STATISTICS/POPULATION BIOLOGY					
population biology	Lee Eberhardt, PhD			X	
statistics	Doug Robson, PhD			X	
DECISION ANALYSIS					
	Ken Reckhow, PhD			X	
	James Ruttener, PhD			X	
MICROBIOLOGY					
	Joan Braddock, PhD				X
MARINE CHEMISTRY					
	Jeffrey Short				X
GIS					
	Art Weiner, PhD				X
TOXICOLOGIST					
	John Stegeman			X	
RESTORATION PLANNING WORK GROUP					
	John Strand, PhD		X		
	Karen Klinge		X		
	Mark Kuwada		X		
RESTORATION TEAM					
	Mark Broderson	X			
	Pantela Bergmann	X			
	J. Jerome Montague, PhD	X			
	Byron Morris, PhD	X			
	Ken Rice	X			

**LIST OF WORKSHOP PARTICIPANTS**

**APPENDIX C**

## ATTENDANCE AT WORKSHOP

RESOURCE SERVICE REPRESENTED	PERSON	AGENCY/ASSOCIATION
<b>OVERVIEW, MARINE ECOLOGY</b>		
	Bob Spies	Applied Marine Sciences (API)
	Don Boesch	University of Maryland
	Gail Irvine	U.S. National Park Service
<b>MARINE MAMMALS</b>		
sea otters	Jim Bodkin	U.S. Fish and Wildlife Service
river otters	Jim Faro	Alaska Department of Fish and Game
river otters	Vern Byrd - <i>also sea birds</i>	U.S. Fish and Wildlife Service
<b>FISHERIES</b>		
salmon	Phil Mundy	Columbia Basin Intertribal Fish Commission, Portland, Oregon
<b>BIRDS</b>		
seabirds	Vern Byrd - <i>also river otters</i>	U.S. Fish and Wildlife Service
bird restoration	Dennis Heineman	Consultant, Peer Review - API
seabirds	Michael Fry	University of California, Davis
seabirds	Sam Patten	Alaska Dept. of Fish and Game
<b>ARCHAEOLOGY</b>		
	Martin McAllister	Archaeological Rsc. Invest.
<b>RECREATION</b>		
	Jim Richardson	Resource Econ., Inc.
	Jon Isaacs	Jon Issacs and Associates
<b>ECONOMICS</b>		
	Jeff Hartman	Alaska Department of Fish and Game
<b>STATISTICS/POPULATION BIOLOGY</b>		
	Doug Robson	Consultant, Peer Review - API

---

**RESOURCE****SERVICE****REPRESENTED****PERSON****AGENCY/ASSOCIATION**

---

**MARINE CHEMISTRY**

Jeffrey Short

National Marine Fisheries Service

**COASTAL COMMUNITIES**

Ray Highsmith

University of Alaska, Fairbanks

**RESTORATION TEAM**

Mark Broderon

Alaska Dept. of Environmental Conservation

Pamela Bergmann

Department of Interior

Marty Rutherford

Alaska Department of Natural Resources

J. Jerome Montague

Alaska Department of Fish and Game

Byron Morris

National Marine Fisheries Service

Dave Gibbons

U.S. Department of Agriculture

Ken Rice

U.S. Forest Service

**RESTORATION PLANNING WORK GROUP**

John Strand

National Marine Fisheries Service

Carol Gorbis

U.S. Fish and Wildlife Service

Mark Kuwada

Alaska Department of Fish and Game

Ray Thompson

U.S. Forest Service

Karen Klinge

U.S. Forest Service

Chris Swenson

Alaska Department of Fish and Game

Veronica Gilbert

Department of Natural Resources

**REGIONAL CITIZENS ADVISORY COUNCIL**

Dennis Randa

Cook Inlet Regional Citizens Advisory Council

Jim Day

Cook Inlet Regional Citizens Advisory Council

Shelli Vacca

Prince William Sound Regional Citizens  
Advisory Council**OTHERS**

Joe Sullin

Alaska Dept. of Fish and Game

---

GENERAL GUIDANCE ON SAMPLING AND STATISTICAL ANALYSES

APPENDIX D

---

## D. GENERAL GUIDANCE ON SAMPLING AND STATISTICAL ANALYSES

Statistics is playing an increasingly important role in environmental monitoring and research. This has been prompted by a need for valid and repeatable evaluations of elements of environmental (physical, biological, cultural) systems with known levels of confidence and uncertainty. Statistical sample design and analytical techniques can be employed to obtain rigorous descriptions of environmental conditions.

This section summarizes the statistical issues related to any monitoring program designed to evaluate recovery from the *Exxon Valdez* oil spill. It is important that all monitoring programs use comparable, but not necessarily the same, techniques to design the programs, collect and analyze the data, and interpret the results.

Green's Ten Principles (Green 1979) outline considerations for the design of a defensible program.

1. Be able to state concisely to someone else what question you are asking. Your results will be as coherent and as comprehensible as your initial conception of the problem.
2. Take replicate samples within each combination of time, location, and any other controlled variable. Differences among can only be demonstrated by comparison to differences within.
3. Take an equal number of randomly allocated replicate samples for each combination of controlled variables. Putting samples in "representative" or "typical" places is *not* random sampling.
4. To test whether a condition has an effect, collect samples both where the condition is present and where the condition is absent, but all else is the same [may not be possible in the field]. An effect can only be demonstrated by comparison with a control [or a time series].
5. Carry out some preliminary sampling to provide a basis for evaluation of sampling design and statistical analysis options. Those who skip this step because they do not have enough time usually end up losing time.
6. Verify that your sampling device or method is sampling the population you think you are sampling, and with equal and adequate efficiency over the entire range of sampling conditions to be encountered. Variation in efficiency of sampling from area to area biases among-area comparisons.
7. If the area to be sampled has a large-scale environmental pattern, break the area up into relatively homogeneous subareas and allocate samples to each in proportion to the

size of the subarea. If it is an estimate of total abundance over the entire area that is desired, make the allocation proportional to the number of organisms in the subarea.

8. Verify that your sample unit size is appropriate to the sizes, densities, and spatial distributions of the organisms you are sampling. Then estimate the number of replicate samples required to obtain the precision you want.
9. Test your data to determine whether the error variation is homogeneous, normally distributed, and independent of the mean. If it is not, as will be the case for most field data, then (a) appropriately transform the data, (b) use a distribution-free (nonparametric) procedure, (c) use an appropriate sequential sampling design, or (d) test against simulated  $H_0$  data.
10. Having chosen the best statistical methods to test your hypothesis, stick with the result. An unexpected or undesired result is not a valid reason for rejecting the method and hunting for a "better" one.

Although evaluating testable hypotheses is a goal for monitoring, this may not always be possible. In such cases, the methods used should be established and thoroughly documented methods.

The first step in designing a specific monitoring program is to define its purpose (e.g., to determine if the population of bald eagles is recovering in Prince William Sound after the *Exxon Valdez* oil spill). This purpose will be used to develop the rest of the monitoring program, including the specific element(s) that will be monitored to meet the purpose. Statistical theory and methods, in addition to knowledge of the characteristics of and influences on the resource or service to be evaluated, are used to guide the development and execution of the following components of a monitoring program:

- Formulation of testable hypotheses
- Statistical sample design issues
- What to sample
- Where to sample
- How to sample
- When to sample
- Statistical analyses
- Interpretation of results

These elements are addressed in more detail in the following subsections.

## **D.1 FORMULATION OF TEST HYPOTHESES**

Based on the purpose defined for a specific monitoring program, a statement (the null hypothesis,  $H_0$ ) is formulated that addresses the purpose in simple, concrete terms. This null hypothesis identifies the state of the element that is to be tested (e.g., if the purpose of a



monitoring program is to determine if the population of bald eagles is recovering in Prince William Sound after the *Exxon Valdez* oil spill and the recovery monitoring endpoint is population size with an expected increase of 2 percent per year, the null hypothesis could be stated as "There is no statistically significant change in the number of bald eagles residing in Prince William Sound during the breeding season between 1993 and 1994.") Testing this null hypothesis via statistical methods will be the objective of the sampling and analysis process.

It is possible that the data will indicate that the null hypothesis is not likely true. An alternative statement (alternative hypothesis,  $H_A$ ) is formulated that defines a different state of the resource or service. Should a statistical test indicate that the null hypothesis is false, the data can be evaluated in terms of the alternative hypothesis. For example, the alternative hypothesis for the null hypothesis in the previous paragraph could be stated as "There is a statistically significant increase in the number of bald eagles residing in Prince William Sound during the breeding season from 1993 to 1994".

When testing a hypothesis, as shown below, two types of errors exist. Type I error ( $\alpha$ ), the probability of rejecting the null hypothesis when it is actually true, is commonly set at 5 percent. Type I error is also known as the significance level of a test. Type II error ( $\beta$ ) is the probability of accepting the null hypothesis when it is actually false. Decreasing one of these two errors will increase the other.

		$H_0$	
		Accept	Reject
$H_0$	True	Correct Decision ( $1-\alpha$ )	Type I Error ( $\alpha$ )
	False	Type II Error ( $\beta$ )	Correct Decision ( $1-\beta$ )

## D.2 STATISTICAL SAMPLE DESIGN ISSUES

To develop an optimal sampling design for a monitoring program that tests the specified null hypothesis, some statistical issues must be addressed, including the significance level ( $\alpha$ ), power level ( $\beta$ ), sources and magnitudes of variation, and minimum detectable change (MDC).

As noted in the previous section, two types of error may be present in hypothesis testing, Type I ( $\alpha$ ) and Type II ( $\beta$ ). These errors need to be balanced, since decreasing one increases the other. The only way to reduce one error level without increasing the other is to improve the sampling design, (e.g., increasing sample size). A sampling design must adequately and realistically address both types of error.

In environmental monitoring and sampling, many sources of variation occur in addition to those commonly addressed in experimental designs (e.g., within-sample, between-sample, analytical, and random). These additional sources are also present at very different magnitudes and dimensions. An optimal sampling design must therefore address temporal variation, spatial variation, and natural system variations. Replication is one sampling technique that can be used to quantify many of these sources of variation. Data from previous studies may also be useful in evaluating potential sources of variation.

When testing a hypothesis, a level of change exists below which the null hypothesis is not rejected. This MDC of a statistical test is affected by several other test parameters:

- Inherent variation (natural variation, within- and among-sample variation, and analytical variation)
- Sample size (n)
- Significance level ( $\alpha$ )
- Power (1- $\beta$ )
- Temporal and spatial autocorrelation

The MDC should be small enough to meet the needs of the monitoring program but not so small as to require a prohibitively large sample size or reduce the power of the test below an acceptable level. Due to the variability usually found in environmental data and often limited sampling budgets, a balance between the MDC, sample size, significance level, and power has to be reached.

The following function can be used to study the balance between these quantities or evaluate the level of power associated with statistical tests under consideration for a single hypothesis.

$$(Z_{\frac{\alpha}{2}} + Z_{\beta}) * s * \sqrt{2 \frac{(1-R)}{n} * \sqrt{1+\rho(n-1)}}$$

- Where:
- $Z_{\alpha/2}$  and  $Z_{\beta}$  = The normal "Z" values for various levels of  $\alpha$  and  $\beta$
  - $s$  = A quantity that estimates the inherent variation (commonly a standard deviation)
  - $r$  = The temporal autocorrelation, or a quantity that estimates it
  - $n$  = The sample size
  - $\rho$  = The spatial autocorrelation, or a quantity that estimates it

A preliminary sampling effort should be made, if possible, to evaluate the design, evaluate the sampling and analytical procedures, and identify and quantify sources of variation. If the

sampling design does not require extensive modifications, the preliminary data could be included in the monitoring program analyses. Another approach to address the variation issues would be to over-sample and use extensive replication for the first two to three years to ensure adequate sample sizes and to obtain estimates of variation components and then reduce the sample scope for the remainder of the monitoring program.

Any sampling design that is developed for a monitoring program should be flexible. It is quite possible that changes will have to be made after the first or second year to address inadequacies in the design or possible budget constraints, especially if the amounts and primary sources of variation cannot be adequately assessed during the design phase.

### **D.3 WHAT TO SAMPLE**

After defining the purpose of a monitoring program, the resource or service to be sampled is chosen so that the null and alternative hypotheses can be formulated. The state of the resource or service that is being tested should be relevant to the defined purpose of the monitoring program. There will probably be more than one recovery endpoint of the resource or service that can be measured to test the hypotheses. There should be little or no difficulty collecting data on the resource or service, and the data should have the capacity to evaluate the null hypothesis via statistical testing.

Choosing a characteristic of a resource or service that has been sampled in previous studies or monitoring programs may be advantageous. Data from these previous sampling efforts can be used to extrapolate properties associated with the measured characteristic prior to designing the sampling effort. Variability components could be estimated from the previous data to determine adequate sample size. Sampling and analysis problems encountered in prior work could be avoided or accounted for in the current study.

### **D.4 WHERE TO SAMPLE**

The question of where to sample encompasses two issues, that is, the study area and actual sample locations. The study area should encompass the entire area of interest for the monitoring program—with the sample locations cited within this study area. Previous studies can provide insight into appropriate methods and possible pitfalls.

Choosing the actual sample locations has implications for the statistical tests and their interpretation. How the sample locations are chosen influences the relationship between sample locations, variability estimates, and the inference basis for the statistical tests. Conventional statistical analysis methods were developed for data collected as random samples. Random, or probability, samples are considered independent and representative of the population from which they are sampled, and estimates of parameters such as means and variances computed from such samples are unbiased for those populations. By removing the randomness from the sample locations, as in judgment sampling, bias can influence the parameter estimates and restrict the interpretation of statistical tests.

There are three main sampling approaches that yield random samples: (1) random, (2) stratified random, and (3) systematic random. In the random approach, samples are randomly located within the entire study area. In the stratified random approach, if the population of the resource or service under study is known or suspected to be unevenly distributed within the study area, homogeneous subgroups can be formed within the study area and random samples taken from each subgroup. The systematic random approach makes use of a two-dimensional grid that is randomly placed in the study area, and the sample locations are taken as either the intersections of the grid lines or at the same location in each grid area (e.g., the center). Other sampling schemes that produce random samples have been or can be developed from these basic approaches.

## **D.5 HOW TO SAMPLE**

The methods used to collect data in the various monitoring programs should follow standardized protocols. These standardized protocols will ensure the data are consistent, accurate, and comparable between sampling events, monitoring years, and monitoring studies. Standardized protocols are also important to ensure that the data analyzed is of acceptable quality for statistical analysis.

It is likely that many of the standardized protocols exist as a result of previous environmental studies. These will simply need to be assembled into a cohesive set. However, others may need to be developed from scratch, but previous research may provide useful insights into possible methods and potential difficulties.

Sampling methods should be documented in detail, specifying the exact steps to be taken from locating sample sites to shipping the collected samples to the analytical laboratory. Some of the items to include are listed below.

- Locating sample sites
- Collection of field observations (e.g., temperature)
- Collection of sample(s)
- Preparation of field spikes, duplicates
- Preserving, packaging, labeling of samples
- Storage, transportation of samples
- Documentation of samples (e.g., chain-of-custody forms)

Laboratory analytical methods should also be documented in detail; however, some will incorporate state and/or federal protocols. Analytical items to document include:

- Receipt of samples from the field
- Preparation of samples
- Preparation of laboratory spikes, blanks
- Analytical procedures
- Reporting formats, including units and qualifiers
- Documentation of samples (e.g., chain-of-custody forms)

Compositing samples can be used to reduce the costs of analyzing large numbers of samples, increase the sample material available for analysis, and reduce the between-sample variability caused by heterogeneous sample material. However, the consequences of compositing include the loss of ability to estimate between-sample variability. This would need to be addressed in the sampling and analysis design.

## **D.6 WHEN TO SAMPLE**

The decision about when to sample is influenced by many factors. For example, natural factors (such as weather conditions and time of the year) can influence the data that is collected, and organizational factors (such as sampling and analytical costs) can limit the amount and frequency of sample collection.

Historical data, if available, and knowledge of resource or service characteristics can be very useful in determining the best time(s) for sampling. Sampling times should be consistent from year to year (e.g., such as counting bald eagles present during the breeding season only). The severity of the weather in the oil spill area and monitoring constraints (e.g., seasonal migrations of certain species) may also restrict sampling times.

Additionally, biological factors, such as life stage, behavior patterns, abundance and distribution of prey, should also be factored into the decision on when to sample.

## **D.7 STATISTICAL ANALYSES**

There are many statistical analysis methods available for evaluating environmental conditions. The primary focus of monitoring programs is to detect change over time, and several standard analysis methods can be used to this end, such as analysis of variance (ANOVA), trend analysis, and time series analysis. Regression, correlation analysis, and other multivariate techniques can be used to evaluate hypothesized relationships between different variables measured in the monitoring program. Unless special circumstances require, standard analysis methods such as these should be used for the sake of clarity, comparability, and repeatability.

The analysis method used to test the null hypothesis is chosen prior to sampling, and it should be appropriate and rigorous for the stated null hypothesis and sampling methods used. Typically, the significance level ( $\alpha$ ) for a hypothesis test is set at 5 percent. For the chosen analysis method, the assumptions associated with the method must be addressed, since violations of an assumption can compromise the validity of, and confidence in, the analysis results.

Since spatial variability will most likely influence all monitoring data collected to some degree, statistical spatial analysis techniques may need to be considered. Any spatial methods used should be thoroughly researched and carefully applied. Geographic information systems (GIS) may be useful in such analyses.

A specific statistical method discussed at the workshop is a method that evaluates the year-by-year change in oiled sites relative to that at paired reference sites. There are several difficult analysis issues addressed by this method. This approach can be used for sites monitored on a yearly basis, or less often (e.g. every three years). By pairing sites, some large-scale variation can be accommodated inasmuch as the paired sites are proportionately affected. Furthermore, this method does not require any pre-spill data, which often does not exist.

While this method for evaluating the level of change between paired oiled and reference sites is straightforward and may be useful for any monitoring program, it does not replace the need for a sampling and analysis plan that is optimally designed to meet a specific monitoring goal.

This method is expressed as follows:

Design:  $n$  pairs of sites (oiled, reference) are monitored annually.

Data: In year  $t$ ,  $(T_{i,t}, C_{i,t})$  with  $i = 1, 2, \dots, n$

Incremental Relative Change:

$$\left\{ \frac{\bar{T}_{t+1}}{\bar{T}_t} / \frac{\bar{C}_{t+1}}{\bar{C}_t} \right\} \begin{cases} > 1 \text{ suggests "recovery continues"} \\ < 1 \text{ suggests "damage continues"} \end{cases}$$

or, on the logarithmic scale, let

$$\bar{x}_t = \frac{1}{n} \sum_{i=1}^n \{(\log T_{i,t+1} - \log T_{i,t}) - (\log C_{i,t+1} - \log C_{i,t})\} = \frac{1}{n} \sum_{i=1}^n x_{it}$$

so that

$$\sqrt{n} \frac{\bar{x}_t}{s_{x_t}} \begin{cases} > t_{1-\frac{\alpha}{2}, n-1} \\ < t_{\frac{\alpha}{2}, n-1} \end{cases} \rightarrow \begin{cases} \text{"recovery continues"} \\ \text{"damage continues"} \end{cases} \text{ else "don't know"}$$

Recovery: The sequence  $\bar{x}_1, \bar{x}_2, \bar{x}_3, \dots$  converges to zero (in expectation)

Remarks:

- Serial correlation does not damage the individual t-tests, but does complicate testing for convergence.
- Pairing of oiled and reference sites is desirable, but not essential to this approach.
- The same approach would apply if sites were monitored, say, every third year.
- Annual "bay-wide" fluctuations are accommodated by this approach, to the extent that all sites are proportionately affected.
- Within-pair spatial correlation enhances power; between-pair distances should be great enough to make  $r=0$ .
- This method for data analysis does not use pre-spill data.

## **D.8 INTERPRETATION OF RESULTS**

Interpretation of analytical results must take into consideration the tested hypotheses, sampling methods, and analysis methods and associated assumptions. The conclusions reached and interpretations made must be supported by the data and take into consideration the sampling methods used and the assumptions and restrictions associated with the analytical methods.

When drawing conclusions about environmental data, caution must be used. While a significant change may have been detected, can it be attributed to a recovery process or is it a result of some natural event (e.g., a decrease in predator population)? Because so many factors are not measured, conclusions about relationships between elements should be viewed as associations and not necessarily cause-and-effect relationships. Establishing cause-and-effect relationships in the environment requires controlling all factors not measured.