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Proceedings of the Workshop
SCIENCE FOR THE RESTORATION PROCESS
Held in Anchorage, April 13-15

I. Introduction

In April, 1994, the *Exxon Valdez* Oil Spill (EVOS) Trustee Council sponsored the workshop "*Science for the Restoration Process*" in Anchorage, Alaska. This meeting was one of a series of workshops beginning in Cordova in December, 1993, organized in response to the public's need and desire to know what remains injured by the oil spill, and whether anything further can be done to restore the injured resources. In particular, the need for an ecosystem approach to restoration questions has been identified as a high priority. The workshops have been attended by the Trustee Council Chief Scientist and science peer reviewers, agency representatives, principle investigators for restoration projects, Public Advisory Group (PAG) members, and other interested public participants. As the workshops have progressed, a substantial (although certainly not complete) scientific consensus emerged on research priorities regarding factors constraining the recovery of non-recovering resources, and ecosystem approaches likely to be fruitful. These workshop proceedings represent an initial attempt to summarize that consensus into a science strategy for the restoration process.

The consensus research priorities serve two purposes. First, they provide general guidance to proposers regarding the relative importance of factors that may be constraining restoration, so that scarce science dollars may be directed most effectively. Second, they provide an initial model of how the ecosystem is currently thought to interact with the resources of interest. It is anticipated that each year this model will be reviewed and modified if necessary based on new field results. Thus, this initial consensus statement is to be considered a dynamic working document that is a key product of an adaptive management process.

Resources injured by the spill are best evaluated from the dual perspectives of the resources *per se*, and the ecosystem that embraces them. Because people interact with ecosystems through specific resources, this science strategy primarily focuses on individual species (e.g., pink salmon and herring, specific sea birds and mammals, etc.) and specific biological communities (e.g., intertidal and shallow subtidal marine communities) that have been injured by the spill, and are apparently not recovering or are recovering very slowly. Because these non-recovering resources interact with the larger ecosystem, however, natural ecosystem effects on non-recovering resources cannot be ignored. These effects are often much greater than human impacts, and failure to consider them may lead to false conclusions of prolonged spill-related injuries, or obscure more subtle spill-related effects.

Although this science strategy employs an *ecosystem approach* to specific non-recovering resources, it is *not* a strategy for an *ecosystem study*. It is important to recognize that the goal of understanding the marine ecosystem of the spill-affected area lies far beyond the means at hand. With careful management, scientific review and broad public participation, a better understanding of the parts of this ecosystem that affect non-recovering resources may be attainable with available means, and this may produce substantial collateral benefits.

Long-term, integrated monitoring is fundamental to any ecosystem approach. Monitoring involves collecting field data, whether to evaluate the recovery of injured resources, to discover why non-recovering resources are not recovering more quickly, or to evaluate the efficacy of restoration efforts. These different purposes require different time-scales and frequencies. For example, adequate recovery monitoring requires observations over many years or even decades, but not necessarily each year. In contrast, research and restoration monitoring often require observations that are more intensive but less protracted. This science strategy seeks to provide a framework that identifies appropriate time-scales and sampling frequencies for these different monitoring efforts, with an eye to integrating these efforts as much as practical.

Integrated monitoring can enhance the scientific value of collected data in addition to lowering costs. Where specific sampling stations and times for different monitoring goals may be appropriately combined, the collected data are directly and mutually comparable, which can result in insights that are unattainable through isolated sampling. However, the difficulty of achieving the necessary coordination increases with the scale of the effort, resulting in a substantial administrative challenge. Similar considerations apply regarding integration to lower sampling costs. For example, samples for recovery, research, and restoration monitoring may all be amenable to simultaneous collection in some cases, but may be inappropriate in other cases due to conflicting goals for recovery monitoring. Resolution of these cases will also entail careful planning and administrative effort.

Conceptual Strategy

The conceptual strategy used during this workshop was to identify injured resources (damage assessment), determine whether these resources are recovering (recovery monitoring), try to find the reasons why some resources are not recovering (research), and then see whether anything can be done about them (general restoration).

Identification of injured resources was a major goal of the *Exxon Valdez* Natural Resource Damage Assessment (NRDA) effort, and the results of that work provide the initial focus for this strategy. The resources identified as injured are the subjects of recovery monitoring to either verify recovery, or alternatively to identify resources that apparently are recovering only very slowly or not at all, i.e., non-recovering resources.

For the non-recovering resources, the scientific challenge is to identify the factors that constrain recovery and possible methods to affect or accelerate recovery. This is challenging because of the numerous possibilities. For example, herring returns to PWS may be low due to lingering toxic effects of the oil spill, to other human impacts such as over-fishing, or to any of several natural ecosystem factors such as predation, absence of prey at critical life stages, or disease, either singly or in combination. A major goal of the science workshops was to find a sense of scientific consensus regarding the most plausible factors influencing the recovery of injured resources, and to identify associated research approaches.

The factors constraining recovery may be broadly distinguished according to their relation to the oil spill. Spill-related factors include ecotoxicological effects such as oil toxicity (including heritable genetic damage), and effects on the structure of biological communities consequent to high mortality of key ecological species such as sea otters immediately after the spill. On the other hand, natural ecosystem factors such as predation, prey availability, reproductive habitat, disease, etc., continuously exert profound effects on species and communities. For this reason, an ecosystem approach is needed to complement ecotoxicological approaches, which generally focus on single species or issues. In addition, other human impacts (e.g., over-fishing) may also need to be considered in some cases, together with the possibility that some of these factors may interact synergistically. Nonetheless, the most fundamental question regarding non-recovering resources is whether the non-recovery is due to lingering effects of the spill, or is caused by other factors unrelated to the spill. The extent to which this question is clearly answered will provide the most meaningful measure of the success of this science strategy.

General Restoration Strategy

In some cases, the results of better scientific understanding of factors constraining recovery of non-recovering resources may suggest ways that recovery may be hastened through intervention. For example, oil remaining in some mussel beds may be removed to reduce the biological availability of the oil. These kinds of efforts should be monitored to evaluate efficacy and also the extent of additional injury that may collaterally result from the intervention. This science strategy therefore includes a section on general restoration, to insure that restoration efforts have a firm scientific basis, are appropriately integrated with recovery and research strategies, and are critically evaluated to see what works.

Guide to the Following Sections

The three major sections that follow are organized according to the conceptual strategy presented above. The strategy for recovery monitoring is discussed first. Both time-scales and observation frequencies appropriate for each of the various injured resources are proposed, as are criteria for deciding when recovery is complete. Next is the strategy for research, where an attempt is made to identify and to some extent prioritize factors thought most to constrain recovery by scientists and others that participated in the workshops. The restoration section is last, where specific restoration efforts and associated monitoring and evaluation strategies are presented.

The material in the following sections, and particularly the prioritization in the research section, are offered as a starting point for investigation, further debate, and modification as new evidence becomes available. Annual workshops open to the public as well as to participating scientists will provide a forum for information exchange, debate, and revision, ensuring that the science strategy will be adaptively managed on a continuing basis to make full and immediate use of new results.

II. Recovery Monitoring Strategies

Recovery Monitoring Strategies identify the long-term approach for determining the status of injured resources and services, their rate of recovery, and when they have achieved the recovery objectives. For those injured resources or services that are considered to be recovering at a sufficient rate, monitoring of natural recovery is the only restoration effort required. For injured resources and services that are not recovering or are recovering slowly, additional scientific research and directed general restoration may be required to determine the causes for lack of recovery, and to affect or accelerate recovery. Recovery monitoring of these resources will determine changes in their status in response to natural causes or restoration actions. This need for recovery monitoring of general resource status is distinct from monitoring activities that may be required for research projects or to determine the success of specific restoration projects.

Recovery status and objective, monitoring strategy, monitoring schedule, and estimated recovery time have been developed for each injured resource or service. This information is provided in an alphabetized listing of injured resources and services in Appendix B, "Objectives and Strategies by Resource and Service." Table 1 summarizes the recovery strategies and monitoring schedule proposed for each injured resource and service.

The Monitoring Strategies contained in Table 1 and Appendix B were developed and reviewed by workshop participants. They will be used to plan the Recovery Monitoring Component of annual work plans for the length of the Settlement, pending additional public and scientific review. The Monitoring Strategies are not static but are subject to review and modification as new information is obtained. In some cases, revisions to recovery status or objectives have been proposed by workshop participants that change or are inconsistent with previously accepted scientific conclusions. These contentious cases are given in Appendix C; scientific review of these substantive changes will be undertaken to resolve the differences in time for preparation of the 1995 Annual Work Plan.

In principle, recovery monitoring of a resource or service is not required every year. In some cases, however, long-term monitoring cannot be defined until more information on the status of the resource is acquired in 1995 or 1996.

Table 1. Recovery Monitoring: Strategies and Frequencies for Injured Resources and Services

RESOURCE	RECOVERY	MONITORING FREQUENCY, Yrs	1995	1996	1997	1998	1999	2000	2001	> 2001
MARINE MAMMALS										
HARBOR SEALS	NOT RECOVERING	TREND COUNTS, 1	●	●	?					
KILLER WHALES	RECOVERING	PHOTO-IDENTIFICATIONS, 2	●		●		●		●	?
SEA OTTERS	NOT RECOVERING	AERIAL SURVEYS, 2	●		●	?				
		CARCASS COLLECTIONS, 1	●	●						
TERRESTRIAL										
RIVER OTTERS	UNKNOWN	FIELD SURVEYS, 1	●	?						
BIRDS										
BALD EAGLES	RECOVERING	POPULATION SURVEYS, 5	●					●		
BLACK OYSTERCATCHERS	RECOVERING	BOAT SURVEYS, 3		●			●		?	
COMMON MURRES	NOT RECOVERING	POPULATION SURVEYS, 3		●			●			●
		PRODUCTIVITY SURVEYS, 1	●	●	●	●	●	?		
HARLEQUIN DUCKS	NOT RECOVERING	POPULATION SURVEYS, 3	●			●			●	?
		PRODUCTIVITY SURVEYS, 1	●	●	●	●	●	?		
MARBLED MURRELETS	NOT RECOVERING	BOAT SURVEYS, 3		●			●			?
PIGEON GUILLEMOTS	NOT RECOVERING	BOAT SURVEYS, 3		●			●			?
		NAKED ISLAND COUNTS, 3		●			●			?

RESOURCE	RECOVERY	MONITORING FREQUENCY, Yrs	1995	1996	1997	1998	1999	2000	2001	> 2001
FISH & SHELLFISH										
Cutthroat Trout & Dolly Varden	Unknown	Growth rates, 3	●			●			?	
Pacific Herring	Not Recovering	Health & spawning biomass, 1	●	●	●	●	●	●	?	
Pink Salmon	Not Recovering	Egg mortality, 1	●	●	●	?				
		Returns per spawner, 1	●	●	●	?				
Rockfish	Unknown	None								
Sockeye Salmon										
Kenai River	Not Recovering	Fry abundance, 1	●	●	●	●	●	●	●	?
		Smolt outmigrations, 1	●	●	●	●	●	●	●	?
Red Lake	Recovering	Smolt outmigrations, 1	●	●	?					
Akalura Lake	Not Recovering	Smolt outmigrations, 1	●	●	●	●	●	●	●	?
OTHER RESOURCES										
Archeological Sites & Artifacts	Nonrenewable	Index sites, 1	●	●	●	●	●	●	?	
		"Cross-check" sites, 2	●		●		●		?	
Intertidal Organisms	Recovering (some)	PWS sites, 2	●		●		?			
		GOA sites, 2		●		●		?		
	Not Recovering (some)	Herring Bay, 1	●	●	?					
Clams		Density and size, 1	●	?						
Persistence of Oil										
Shorelines	Recovering	Shoreline Assessment, 1	KAP	PWS	?					
Mussel Beds	Not Recovering	Sediment PAH, 3	1/3	1/3	1/3	?				
Subtidal Sediments	Recovering	Hydrocarbons, bile, ?	●	?						

RESOURCE	RECOVERY	MONITORING FREQUENCY, Yrs	1995	1996	1997	1998	1999	2000	2001	> 2001
SUBTIDAL ORGANISMS	RECOVERING (SOME) NOT RECOVERING (OTHERS)	EELGRASS, ?	●	?						

III. Research Strategies

Research for the Restoration Process must focus on why some injured resources are not recovering or are recovering very slowly. The most fundamental question regarding these resources is whether the non-recovery is due to lingering effects of the spill, or is caused by other factors unrelated to the spill. The Trustee Council has recognized, however, that a single-species approach to restoration is not adequate. The first policy stated in the *Draft Restoration Plan* is that the restoration program will take an **ecosystem approach.** Understanding why specific injured resources are not recovering will require a better understanding of how these resources interact with and are influenced by ecosystem-level processes.

The challenge in developing a research strategy is to balance the resource-specific focus with the need for ecosystem context. The fiscal resources dedicated to research are finite, requiring setting priorities among the large range of research issues relevant to the injured resources and the ecosystem upon which they depend. One purpose of the workshop "*Science for the Restoration Process*" was to bring together scientists, public participants, and the Trustee Council work force to identify the critical research issues, and set priorities for these issues. These priorities provide guidance to the development of the research component of the 1995 Work Plan. Project ideas that address issues that have been identified as high priority will obviously have an advantage in the competition for funding.

Research needs were considered from two perspectives at the workshop. First, interdisciplinary work groups (IWGs) were formed to consider research directed at specific suites of injured resources: fish, birds, marine mammals, nearshore organisms and sediments, and archaeological resources. Then, the participants considered research from the perspective of the pelagic and nearshore ecosystem components, and, at a follow-up meeting, the upland ecosystem component. This section attempts to summarize the research strategies and priorities determined by the workshop participants. The basis for this section ~~were~~ was the detailed notes submitted by the coordinators of the IWGs and the ecosystem component groups; these notes are included in the workshop proceedings as Appendix A.

Factors Influencing Recovery

Lists of factors that could be influencing recovery of injured resources were developed in both the resource-specific groups and the ecosystem component groups. These factors can be organized into three general categories: **(1)impacts of oiling; (2)other anthropogenic factors; and (3)ecosystem processes.**

Impacts of oiling include the continued effects of the oil spill on the injured resources. Two types of continuing impacts were identified. First, resources can be suffering from oil toxicity, the result of exposure to oil by either physical contact or ingestion of contaminated prey. These effects can be due to previous exposures to oil, or to continuing exposure to persistent contamination. For example, herring recruiting to the spawning population in 1993 and 1994 may have been acutely exposed as larvae, and harlequin ducks that forage in oiled mussel beds may be suffering continued chronic exposure. Second, heritable genetic damage is a concern for some populations of fish. Genetic damage may occur not only to the year class that spawned or were exposed during the period of acute oiling, but can also be passed down to the next generation.

Other anthropogenic factors are those human activities besides the oil spill event that could be influencing recovery of injured resources. Three types of human activity were identified: (1) Resource exploitation (direct harvest, incidental take, and other disturbances); (2) Effects of hatcheries in Prince William Sound; and (3) Upland development (logging, mining, urbanization, and road construction).

Ecosystem processes are the physical and biological mechanisms that determine biological productivity, population dynamics, and community structure. Nine general types of ecosystem processes were identified: (1) climate/physical oceanography; (2) prey availability; (3) competition; (4) predation; (5) alteration of community structure; (6) behavior changes due to population structure shifts caused by oil-induced mortality; (7) recruitment processes; (8) limitations of reproductive habitat; and (9) disease.

Matrix of Factors and Injured Resources

The non-recovering resources are not necessarily affected by the same factors, or to the same degree by a particular factor. One of the purposes of this workshop was to identify research priorities for determining what factors are constraining recovery. These research priorities are summarized in Table 2. The resources are limited to those biological resources that were injured by the oil spill but which are not recovering or are recovering slowly, and archaeological resources. Specific details on the priority of resource-specific issues and ecosystem processes are given in their respective sections below, and

Table 2. Summary of research priorities on factors potentially influencing recovery of non-recovering injured biological resources and of archaeological resources; an interpretation of the workshop findings.

				RESOURCES								
Factors Influencing Recovery	Herr	Pink Salm	Sock Salm	Comm Murre	Marbl Murre	Pigeo Guill	Harle Duck	Sea Otter	Harb Seal	Intertid al	Sub tidal	Arch
				IMPACTS OF OILING								
Oil Toxicity	**HIGH**	Low				Med.	**HIGH**	**HIGH**	Low	Low	Low	
Heritable Damage	**HIGH**	**HIGH**										
				OTHER ANTHROPOGENIC FACTORS								
Resource Exploit.	Low	Low	Low		Med.	Low		Low	**HIGH**			**HIGH**
Effects of Hatcheries	Low	**HIGH**		Low	Low	Low			Low			
Upland Development	Low	Low	Low		Med.							
				ECOSYSTEM PROCESSES								
Clim./Oceanography	**HIGH**	**HIGH**		**HIGH**	**HIGH**	**HIGH**	Low	Low	Med.	**HIGH**	**HIGH**	
Prey Limitation	**HIGH**	Med.	**HIGH**	**HIGH**	**HIGH**	**HIGH**		**HIGH**	**HIGH**	Low	Low	
Predation	**HIGH**	**HIGH**	**HIGH**	**HIGH**	**HIGH**	Med.	Low	Low	**HIGH**	**HIGH**	**HIGH**	
Competition		**HIGH**	**HIGH**							**HIGH**	**HIGH**	
Community Structure			**HIGH**					**HIGH**		**HIGH**	**HIGH**	
Behavioral Changes				Low								
Recruitment Processes	Med.	Low					**HIGH**	Low	Low	**HIGH**	**HIGH**	
Reproductive Habitat	Med.	Low	Low									
Disease	**HIGH**			Low				Med.	Med.			

in Appendix B. These priorities do not indicate the significance of a factor on the overall productivity or abundance of a resource, but rather reflect the potential for research to determine if a factor is constraining restoration of the impacts of the oil spill on the resource. Several important generalizations concerning research direction are indicated by the pattern of high-priority cells in Table 2.

Continued impacts of oiling were considered high-priority factors in the lack of recovery for four of the 11 biological resources listed. Oil toxicity was a high-priority issue for three species: herring, harlequin duck, and sea otter. The potential for genetic damage was a high-priority issue for two fish resources, herring and pink salmon. These two types of impacts are primarily ecotoxicological effects on the specific resources.

Other anthropogenic factors were identified as having a potential influence on eight of the non-recovering biological resources, but were flagged as high-priority issues for only two biological resources and for archaeological resources. Resource exploitation was considered a high-priority issue for harbor seals and archaeological resources. Resource exploitation was not considered a high-priority factor in the lack of recovery for the three resources that are target species for commercial exploitation: herring, pink salmon, and sockeye salmon. This rating assumes that harvest management strategies will be designed to insure appropriate escapement to the spawning populations. Such strategies may require additional management efforts to ensure escapement of injured populations while allowing harvest of non-injured populations. Effects of hatcheries were identified as a potential factor for six of the biological resources, but was a high-priority research issue for only pink salmon. Upland development was identified as an issue for four of the non-recovering resources, but was not considered a high-priority research issue for any.

Three types of ecosystem processes were identified as factors influencing recovery for virtually all of the biological resources shown in Table 2: climate/oceanography, prey limitations, and predation mechanisms. Both climate/oceanography and prey limitation were identified as factors for 10 of the 11 biological resources considered, and were high priority for seven. Predation was identified for all 11 resources, and was high priority for eight. Alteration of community structure was a high-priority research issue for four injured resources, competition was considered a high-priority factor for four resources, recruitment processes for three resources, disease for one resource, and reproductive habitat limitations and behavioral changes for none.

The pattern of priorities for ecosystem processes influencing recovery of specific resources are best understood in the context of the different ecosystem components in which they occur. Climatic and oceanographic processes are important for resources in both the pelagic and nearshore ecosystems. Intertidal and subtidal organisms form distinct biological communities in a nearshore ecosystem which has been dramatically altered by oiling and related clean-up activity. Community structure and the trophic processes that control community structure (predation and competition), physical processes, and recruitment events to re-establish key species are thus the principle areas of interest in understanding the lack of recovery of these communities. Similarly, sockeye salmon are dependent on an upland aquatic ecosystem whose community structure has been altered due to spawner overescapement; trophic processes controlling prey abundance are the priority research needs. Predation and/or prey limitation are consistent high-priority issues for animals that forage in the pelagic ecosystem: harbor seals, salmon, herring, and seabirds.

In addition to these patterns, there are several resource-specific special cases. Disease is currently an extremely critical concern in the recent decline of herring biomass in Prince William Sound. Competition is flagged as a high-priority issue for pink salmon because of the concern over competitive interactions of wild and hatchery fish. Failure in the recruitment of harlequin ducks in Western Prince William Sound is a high-priority concern.

Priority Resource-Specific Issues

Fish. The Fish IWG discussed research priorities for non-recovering fish species (herring, pink salmon, sockeye salmon). Pink salmon and herring were directly injured by exposure to oil or oil-contaminated prey in Prince William Sound. Both resources have declined precipitously in the past two years. High priority was given to continued research on ecotoxicological linkages of previous exposure to continued injury at the population level. These injuries could involve both the expression of lethal and sublethal impacts from oil exposure in early life-history stages, and heritable genetic damage.

Research on ecosystem processes such as climate/oceanography, prey limitation, and predation, was also given high priority for understanding why herring and pink salmon are not recovering in Prince William Sound. A hypothesis for an ecosystem approach to determining how processes in the pelagic ecosystem may control fluctuations in these fisheries resources has been identified. This hypothesis is that mortality and growth of pink salmon and herring in Prince William Sound are controlled by the standing biomass of zooplankton, as influenced by atmospheric and oceanic processes. The average residence time of the Sound's waters and the strength of advective transport of deeper waters from the Gulf of Alaska into the Sound control the standing biomass of zooplankton. When zooplankton are abundant, predation pressure on juvenile salmon and herring is relatively low, and survival of the juveniles is higher. If zooplankton abundance is low, predatory fish and birds switch from a zooplankton diet to juvenile salmon and herring, thus reducing survival of the juveniles.

Other specific ecosystem processes were also identified as high-priority issues for herring, including the role of viral hemorrhagic septicemia (VHS) on recruitment, the advective transport of herring larvae from rearing areas in the Sound, and the quality of winter conditions on the survival and reproductive success of the herring population.

The effects of large-scale enhancement of pink salmon in Prince William Sound on the recovery and productivity of wild populations of pink salmon was also given a high priority for research. The Fish IWG discussed the difficulty of defining actual causative mechanisms of variations in abundance of populations by correlative or process-modeling approaches. They decided that large-scale manipulations of hatchery releases, involving annual and intra-annual variations in the numbers, location, time, and size of fish released, could be a powerful tool to explicitly test for both wild/hatchery stock interactions and mechanisms that influence or limit carrying capacity for pink salmon in Prince William Sound.

The priority issue for injured populations of sockeye salmon are fundamentally different than those for the other fish species because of how injury was sustained. Overescapement to specific rearing lakes because of spill-related fishery closures in 1989 resulted in reduced production of sockeye salmon from these lakes. While smolt production may have recovered in Red Lake, smolt production from Akulara Lake and Kenai River lakes has not recovered, but has continued to decline. The hypothesis for these continued declines in production is that excessive grazing of zooplankton by the large number of fry recruiting to the lakes resulted in an alteration of the structure of the zooplankton community, and that trophic-level interactions are now restricting recovery to pre-spill status. Understanding the trophodynamics of these terrestrial aquatic ecosystems is the key research issue in determining restoration strategies for sockeye salmon.

All of the injured fish species are important commercial and sport fishing resources. As such, increased management resolution has been necessary to effectively manage the resources so that harvest opportunities can continue to the extent possible without negatively impacting the recovery of damaged populations. These types of management requirements were identified for several of the injured fish resources (Appendix B). The IWG felt that additional increments of management effort beyond the normal agency requirements should be considered general restoration projects.

Birds. The Birds IWG discussed the status and research priorities for the non-recovering bird resources: common murre, marbled murrelet, pigeon guillemot, and harlequin duck. This group considered a list of six major factors that may be limiting the recovery of these species. Four of the six were categorized as ecosystem processes: food limitation, predation, nest site limitations, and disease. The other two were oil toxicity (impacts of oiling, including behavioral changes due to population structure shifts); and human disturbance (including incidental catch in fisheries).

The factors identified as influencing recovery for murres, murrelets, and guillemots, species that feed largely on pelagic forage fishes (capelin, herring, and sandlance), were very different from the harlequin duck, which forages almost exclusively in the intertidal. The high-priority research issues for the former group were ecosystem processes: climate/oceanography, prey limitation, and predation. For all three of these species, climatically-driven shifts in the composition of prey species are hypothesized to control population levels, productivity, overwinter survival, and distribution. Predation of eggs and nestlings is an alternate hypotheses for the lack of recovery of these resources. Mammalian and/or avian predation is considered a high- priority issue for murres and murrelets, and medium priority for guillemots. None of the factors under impacts of oiling or other anthropogenic factors were ranked as a high-priority issue for murres, murrelets, and guillemots (Table 2). Oiling of eggs was considered an issue of medium priority for guillemots, as were resource exploitation (incidental gillnet catch) and upland development (logging) impacts on marbled murrelets.

In contrast, the high-priority research issues for harlequin ducks were oil toxicity and recruitment processes. The breeding population of harlequin ducks in the western Prince William Sound has suffered consistent reproductive failure. The reasons for this chronic recruitment failure since the spill are unknown, but the leading hypothesis is that ingestion of oil-contaminated prey from foraging in oiled mussel beds has affected the reproductive success of the resident birds.

Marine Mammals. The Marine Mammals IWG developed broad hypotheses to address marine mammals in PWS in a general sense. The group felt that most of these concepts pertained to seabirds and other predators in PWS as well as to marine mammals, but because this was specifically designated a marine mammal working group, the hypotheses were framed relative to marine mammals. The hypotheses were developed after taking into consideration the recent status of marine mammals in PWS as well as management needs for the species.

Injured marine mammal resources in Prince William Sound that are not recovering are harbor seals and sea otters. Harbor seals in PWS and the northern Gulf of Alaska have been declining for over a decade. The EVOS caused additional mortality in the spill area. In the four years since the EVOS, seal numbers have not shown any indication of recovery. In contrast, seals in southeast Alaska and Canada appear healthy and increasing. The reasons for the general decline in the northern Gulf and PWS are unknown, but limited (or changing) availability of prey, particularly forage fishes, has been suggested as a cause for the decline. It is not possible, however, to eliminate other causes such as disease, predation by killer whales, harvest, or take by fisheries, or several of these factors in combination. Of these factors, hypotheses relating to prey limitation, predations, and resource exploitation were given highest priorities (Table 2). The specific priority research hypotheses: (1) The decline in harbor seals in PWS (and the Gulf) has occurred primarily because of changes in the availability of prey, particularly forage fishes; (2)Predation by killer whales has caused or exacerbated the harbor seal decline, and/or prevented recovery; and (3)Current declines and lack of recovery in harbor seals are due to anthropogenic causes (fisheries take, subsistence harvest, disturbance).

Prior to the EVOS, sea otters in PWS had been increasing and expanding their range into new areas of the Sound. Several thousand sea otters died immediately following the EVOS.

Furthermore, in the two years following the spill, mortality of prime age adults continued to be abnormally high and juvenile survival was lower in the oiled area than in unoiled eastern PWS. As of 1993, overall numbers of otters in the spill area appear to be increasing, but densities remain low in some affected areas. Adult mortality appears to have returned to normal, but juvenile survival is still lower in the oiled area. It is unknown whether this persistent difference between eastern and western PWS is due to differences in habitat or residual effects of the EVOS. For sea otters, high priority was given to questions focused on continued impacts of oiling, both by direct toxicity and altered community structure, and on prey limitation on recovery. Specific research hypotheses relative to these factors are:
(1) Direct exposure to hydrocarbons and/or ingestion of contaminated prey has impacted current or future survival and reproductive success of sea otters in PWS; and (2) EVOS-induced changes in populations of benthic prey species have limited re-occupation of sea otter habitat and the recovery of sea otters in oiled areas.

The Marine Mammals IWG also identified other general issues that were considered important, but were not flagged as high of a priority relative to the non-recovering resources. These issues included research on genetic stock differentiation of marine mammals inside and outside Prince William Sound; definition of habitat effects and oceanographic processes on recruitment, growth, condition, and survival; and impacts of disease on harbor seals and sea otters in Prince William Sound.

The group also identified a list of four data compilation and synthesis tasks that need to be addressed: (1) Historical data (about marine mammals, seabirds, oceanography, fishes) should be analyzed across species and trophic levels and synthesized to provide better insight into ongoing ecosystem changes; (2) Information needs to be collected and compiled on what constitutes important marine mammal habitat in order to effectively protect or manage such areas; (3) Toxicology data collected following the EVOS should be synthesized across species and trophic levels; and (4) A database should be maintained to ensure that data about marine mammals and other species in PWS are available to other scientists and to the public.

Nearshore Organisms and Sediment. The Nearshore IWG considered what processes are limiting the recovery of injured resources that include a diverse biological community including plants, invertebrates, birds, and mammals, as well as environmental hydrocarbons present as contaminates in mussels and sediments. The work group identified seven general hypotheses that described factors influencing recovery.

H_0 1. The EVOS-induced changes in populations of dominant competitors and resident predators in the nearshore region are limiting recovery of benthic communities. (Competition/predation hypothesis)

H_0 2. Recovery of nearshore resources damaged by EVOS is limited by recruitment processes. (Recruitment processes)

H_0 3. Initial and/or residual EVO in benthic habitats has a toxicological effect limiting the recovery of benthic communities. (Oil toxicity, contact exposure)

H_0 4. EVOS-induced changes in populations of benthic prey species have influenced the recovery of benthic foraging predators and affected subsistence use. (Limited prey, bottom up perspective)

H_0 5. EVOS-induced changes in top predators and/or human use have influenced the recovery of EVOS injured benthic prey populations. (Predation, top down perspective)

H_0 6. Initial and/or residual EVO on benthic habitats and in or on benthic prey organisms has had an effect on the recovery of benthic foraging predators. (Oil toxicity, ingestion exposure)

H_0 7. Physical processes limit the recovery of nearshore ecosystems. (Physical limitations)

These hypotheses were incorporated in constructing the matrix of factors influencing recovery (Table 2). Five of the hypotheses (1,2,4,5,7) involve ecosystem processes, either physical factors or trophic interactions. All five also explicitly refer to the alteration in community structure by direct impacts of the oiling (and cleanup) on benthic organisms or by removal of keystone predators. The other two hypotheses (3,6) involve impacts of oiling from initial or continuing exposure to oil from direct contact or ingestion. Because of time constraints, the Nearshore IWG did not assign factors to specific injured resources, or set priorities for the research issues; these decisions were deferred to the Nearshore Ecosystem Work Group. This is especially appropriate for intertidal and subtidal organisms that form distinct communities in a nearshore environment, where the disruption and recovery of community structure is the primary concern.

Archaeological Resources. The Archaeology IWG considered what factors threaten archaeological resources, and how these resources can be utilized as a point of reference from which to identify and measure changes that might be directly or indirectly attributed to the spill. Archaeological sites are a promising source of long-term ecological data. The archaeological record, though often coarse-grained in terms of precise dates, may offer answers to some of the questions posed by contemporary ecosystem scientists who are trying to discriminate between changes that have links to the oil spill and those that represent fluctuations in natural systems over time.

Another source of long-term data may be found through ethnographic and historical research. Native Alaskans over the past millennia have accumulated a rich storehouse of information about the local environment, and though much of this knowledge has been lost in recent years, much still survives. The survival of coastal Native peoples has always depended on accurate, empirical observations about the world and its fickle environment. Historical archives and the memories of non-Native Alaskans also may offer valued information on the operation of the environment in the past.

The IWG identified vandalism of archaeological sites as a major threat to these resources, especially by professional artifact collectors. This factor has been identified in Table 2 for archaeological resources as 'resource exploitation'. The threat of vandalism generates a need for site monitoring and development of cooperative, community-based protection programs to decrease vandalism.

The IWG also identified two hypotheses for using archaeological resources to study cultural dynamics and ecological history. The hypothesis for cultural dynamics is that ecosystem shifts have caused major cultural shifts in the spill area. The hypothesis for ecological history is that archaeological, ethnographic and historic data can produce an informed comparative baseline for EVOS ecosystem studies. Existing archaeological collections may contain faunal/floral samples which will provide critical insights into specific ecosystem problems. Once assessed, the existing data should be supplemented by specific site excavation designed to fill in data gaps.

Priority Ecosystem Issues

Nearshore Ecosystem. The Nearshore Marine Ecosystem Work Group used the seven hypotheses listed above for the nearshore ecosystem to (1)define the mechanisms or factors potentially limiting recovery in the nearshore ecosystem; and (2)define a matrix to set priorities for the particular hypotheses in relation to injured resources in the nearshore. The factors and the resulting ratings for non-recovering resources have been incorporated in Table 2.

After rating the hypotheses by resource, the group decided that for a suite of organisms as diverse as those injured in the nearshore ecosystem, setting priorities for hypotheses across groups of organisms is inappropriate. There are marked differences in the processes that regulate the population dynamics for some of the groups of injured resources. Priorities reflected in Table 2 should be considered as setting priorities for those factors that may be affecting recovery for each injured resource, such as benthic organisms (intertidal and subtidal), sea otters, and harlequin ducks.

The disruption of community structure and the recovery of this structure is a high- priority research issue for the benthic communities pooled in the resource groups 'intertidal organisms' and 'subtidal organisms' (Table 2). The disruption of these biological communities was due both to direct impacts of oiling and associated cleanup on the benthic organisms, and by the removal of keystone predators (e.g., sea otters) from the oiled areas. While the initial disruption of these benthic communities is attributed to oil, continued exposure or toxicity is not considered a high-priority factor influencing their recovery (Table

2). Rather, ecosystem processes that control community structure are now the primary factors influencing recovery. To understand why these benthic organisms are not recovering, research must take a community ecosystem approach to determine the mechanisms responsible for variation in the recruitment, growth, condition, and survival of injured nearshore resources.

Sea otters are an important component of any study examining community structure of nearshore benthic communities, because their foraging activities can define the species composition. Conversely, the recovery of sea otters themselves can be directly influenced by the rate of recovery of injured benthic organisms; food limitations have been identified as a high-priority research issue relative to the re-occupation of oiled habitats by sea otters.

Another high-priority ecosystem research issue is the continued, chronic exposure of injured resources in the nearshore ecosystem to oil trapped in the sediments and byssal thread mats of mussel beds in protected areas. These mussel beds are one of the few sources of unweathered oil remaining from the spill. The original cleanup avoided these mussel beds because of concern that cleaning them would have destroyed the mussels, and thus decreased the food availability for predators such as sea otters and harlequin ducks that forage on the mussels or in the beds. In addition, it was thought that winter storms and other natural processes would remove the remaining oil. However, surveys since 1991 have shown the persistence of crude oil in these mussel beds, and the oiled mussels are a probable route of oil contamination for higher level predators. This continuing exposure may be delaying recovery of some injured resources, particularly harlequin ducks and sea otters. Research concerning the effects of continued exposure from contaminated mussel beds and associated sediments remains a high-priority area for research.

The Group concluded that integrated research in the nearshore ecosystem must include the development of a process for the collection of baseline data relevant to this ecosystem component. Baseline data are generally lacking for the nearshore ecosystem comparable to fisheries harvest, meteorological, oceanographic, and biological data available for the pelagic ecosystem. Baseline data should include distribution and abundance of nearshore plants and animals, physical and environmental data, and archeological, ethnographic/traditional and historical data on the nearshore ecosystem. The group recommended that projects designed to understand processes limiting recovery be integrated into a process for collection of baseline data relevant to the nearshore ecosystem. Ideally, research projects will identify appropriate, cost-effective monitoring tools for developing the long-term data sets essential for analyzing ecosystem variability.

Pelagic Ecosystem. The Pelagic Ecosystem Work Group identified general issues influencing or limiting recovery of injured resources in the pelagic ecosystem. These issues, phrased as questions, were: (1) Is it trophic dynamics (food availability or predation)? (2) Is it physical/oceanographic features (decadal or nutrient cycles)? (3) Is it oil? (4) Is it other anthropogenic factors? (5) Is it disease? (6) Is it habitat? From these broad topics, the group then developed 12 more specific questions which it thought addressed the priority issues in the ecosystem. The group then rated each of these questions as having high, medium, or low priority for each of the six non-recovering injured resources that utilize the pelagic ecosystem: pink salmon, herring, harbor seals, common murres, marbled murrelets, and pigeon guillemots. The questions and rankings were incorporated into the development of Table 2.

Of the questions that directly addressed factors or mechanisms influencing recovery, three were identified as high priority for at least five of the six species considered. The factors were oceanographic cycles; prey limitations; and predation (Table 2). These questions give insight into research priorities that encompass ecosystem process involving the entire suite of non-recovering resources in the pelagic ecosystem. The specific questions are addressed in more detail in the following paragraphs.

Question 1). Are oceanographic cycles (decadal temperature cycles, nutrient cycles, etc.) limiting the availability of prey to higher trophic level consumers? As long-term databases and increasingly sophisticated computers make complicated analyses of historical data possible, it is becoming evident that some changes in populations of fishes, birds and marine mammals may be related to long-term cycles (decades or more). To detect the influence of such cycles on higher trophic levels requires a long-term database and the monitoring of key oceanographic parameters on an ongoing basis. Without such data, it will not be possible to evaluate the effects of climatic changes on the biota. Because climate-induced cycles may be very long term, their effects may be subtle and therefore not obvious to biologists working with short-term data sets. This increases the likelihood that causes for increases or decreases in species abundance may be falsely attributed to an unrelated but plausible cause.

Question 2). Is food limiting, i.e., are changes in the availability of prey (natural or spill-related) affecting the recovery of injured species? Since about the mid-1970s, a variety of species of marine mammals and seabirds in the pelagic ecosystem have been declining in the northern Gulf of Alaska and PWS. These include harbor seals, sea lions, kittiwakes, and marbled murrelets. In contrast, species utilizing nearshore habitats, such as sea otters and sea ducks, have been stable or increasing during the same time period. Some biologists think that differences inherent in the food webs of these species may be responsible for differing trends. However, the mechanisms of the declines are unknown. In the case of seals or sea lions, it may be poor juvenile survival. In the case of seabirds, it may be poor survival of chicks.

All of the declining species rely at least in part on forage fishes such as herring, capelin, sandlance, smelt, and juvenile pollack for food. During the approximately 20 years that marine mammals and seabirds have been declining, the estimates of pollack biomass (based on modelling exercises since no comparable trawl survey data exist prior to the mid-1970s) have increased substantially. The biomass of other species of forage fishes may have decreased, but there are almost no data on these species. The northern Gulf has experienced a warming trend during the same time, which may have affected the abundance of these forage fishes.

A major hypothesis has been developed to specifically address this issue. This hypothesis states that the principal factor limiting the restoration of several injured resources (common murre, marbled murrelet, pigeon guillemot, and harbor seal) is food availability. Food limitation, in turn, may be caused by a recent ecosystem shift in the Gulf of Alaska and Prince William Sound which favors increased production of demersal fishes such as walleye pollack, cod, and flatfish at the expense of the forage species such as capelin, sandlance, and herring on which these injured resources feed.

Question 3). Is predation limiting recovery of injured resources?
Recent declines in some fishes (such as pink salmon and herring) and marine mammals (harbor seals and sea lions) may have significantly changed the availability of prey to top predators and caused them to prey more on other species. For example, when pink salmon are less numerous, eagles may prey more heavily on nesting seabirds. Reduced availability of salmon and herring may cause killer whales to prey more heavily on marine mammals. Furthermore, since numbers of seals and sea lions are greatly reduced, predation may have a far greater impact on the population. Similarly, declines in macrozooplankton availability caused by oceanographic mechanisms may have resulted in prey switching of birds and fishes from macrozooplankton to juvenile herring and salmon, thus causing reduced survival and recruitment of these species.

A major program, SEA (Sound Ecosystem Assessment), was initiated in 1994 which integrates to a large degree research on the above questions in relation to survival of juvenile salmon and herring. The program seeks to test the hypothesis that mortality and growth of pink salmon and herring in Prince William Sound are controlled by the standing biomass of zooplankton, as influenced by atmospheric and oceanic processes. The average residence time of the Sound's waters and the strength of advective transport of deeper waters from the Gulf of Alaska into the Sound control the standing biomass of zooplankton. When zooplankton are abundant, predation pressure on juvenile salmon and herring is relatively low, and survival of the juveniles is higher. If zooplankton abundance is low, predatory fish and birds switch from a zooplankton diet to juvenile salmon and herring, thus reducing survival of the juveniles.

The Pelagic Ecosystem Work Group also rated the long-term monitoring of ecosystem components as a high-priority issue for all injured resources. Detailed understanding of ecosystems requires long-term data sets with which to evaluate normal variation in the distribution and abundance of key ecosystem components. The evaluation of the status and trends of populations is not possible without historical perspective on changes in distribution and abundance of the species and their predators and prey. This does not mean that every species at every trophic level must be monitored. Key ecosystem components should be selected from an interdisciplinary perspective. This might include monitoring oceanographic parameters such as temperature and chlorophyll, zooplankton standing stock in particular areas, and key species of seabirds and marine mammals. Whenever possible, methods should be developed to index trends in abundance, rather than conduct extensive (and expensive) whole-population counts.

These conclusions are very similar to those for the Nearshore Ecosystem Work Group, where the development of a process for the collection of baseline data was given very high priority. Projects designed to understand processes limiting recovery should be integrated into the baseline data collection to the greatest degree feasible. Ideally, research projects pertaining to both the pelagic and nearshore ecosystem will identify appropriate, cost-effective monitoring tools for developing the long-term data sets essential for analyzing ecosystem variability.

The other issues considered by the Pelagic Ecosystem Work Group included continued impacts of oil; genetic stock structure; habitat limitations; effects of hatchery salmon; management tools; other anthropogenic impacts; disease; and use of archaeological information. None of these were considered as high-priority ecosystem research issues. Oil impacts, hatchery effects, management tools, other anthropogenic impacts, and disease were flagged as high-priority issues for one or two specific resources. These issues were addressed in more detail at the resource-specific level.

Upland Ecosystem. The Upland Ecosystem Work Group considered how the ecosystem dynamics of the terrestrial and freshwater aquatic environment should be considered and integrated into the ecosystem approach to restoration of resources impacted by the oil spill. Most impacts of the spill to biological resources occurred in marine environments. Thus restoration issues typically relate to the role of upland habitats in influencing the recovery of specific injured species of birds that forage in marine environments but nest in terrestrial habitats or anadromous fishes.

There are exceptions to the damage from oiling being restricted to marine environments. Specific populations of sockeye salmon were injured because spill-related fishery closures in 1989 resulted in overescapement to some lakes. The subsequent overpopulation of sockeye fry caused large reductions in production of sockeye salmon smolts from these lakes due to density-dependent mortality. Smolt production in two of these lake systems, Akulara Lake and Kenai River lakes, has not recovered, but has continued to decline. The hypothesis for these continued declines in production is that predation from rearing juvenile sockeye salmon has altered the productivity or species composition of the zooplankton community, thus reducing the carrying capacity of the lakes for sockeye salmon juveniles. Research on the community structure and the ecosystem processes determining smolt productivity in these upland freshwater ecosystems is a high-priority research issue for the restoration of injured populations of sockeye salmon.

Other non-recovering injured resources that spawn or nest in the uplands are pink salmon, marbled murrelets, and harlequin ducks. Upland development, especially logging, has been identified as a potential factor influencing recovery for pink salmon and marbled murrelets, and reproductive habitat limitations have been identified as a factor affecting pink salmon and sockeye salmon; but in no case has additional research on these factors been rated as high-priority research needs (Table 2).

The Upland Ecosystem Work Group also considered the issue of nutrient flow from the marine ecosystem to the upland ecosystem via anadromous fish. Anadromous fish can be important sources of nutrients to both aquatic and terrestrial systems within a watershed. At this time, there is no evidence showing that upland resources have been impacted by oil-induced changes in escapement of anadromous salmon; management strategies have been directed at maintaining escapements regardless of whether productivity of anadromous populations have declined. But if oil-damaged populations of salmon continue to decline so that escapement levels are chronically not met, it may be necessary to examine the potential impact of reduced nutrient flow to affected watersheds.

Summary of Priority Ecosystem Issues

The workshop identified five high-priority areas for integrated, ecosystem-level research on processes that may be limiting recovery of injured resources. These issues are listed below; the order of listing does not imply any ranking among the issues.

1. <u>Causes for the failure of Prince William Sound herring and pink salmon production</u>: pelagic ecosystem component.

2. <u>Causes for the long-term decline in some marine mammals and seabirds in the spill areas</u>: pelagic ecosystem component.

3. <u>Alteration of nearshore community structure</u>: nearshore ecosystem component.

4. <u>Continued exposure of injured resources to oil trapped in contaminated mussel beds</u>: nearshore ecosystem component.

5. <u>Alteration of zooplankton community structure in impacted sockeye salmon rearing lakes</u>: upland ecosystem component.

In addition to these five specific issues, identification and long-term monitoring of key ecosystem parameters were recognized as critically important. This type of database development is key to addressing the high-priority ecosystem questions listed above. However, ecosystem monitoring and research that are not necessary for restoring resources and services injured by the spill are not eligible for funding. Research projects directed at understanding ecosystem processes that may be limiting recovery of injured resources should be designed to identify parameters that can be monitored in a cost-effective manner over the long term. In this way, the long-term data sets essential for analyzing ecosystem variability can be developed.

IV. General Restoration

General Restoration projects are activities designed to help an injured resource or service recover. These projects can be divided into one of three categories. These include projects that will 1)increase the rate of recovery; 2)increase the degree of recovery (enhancement); or 3)increase protection for injured resources.

Projects that increase the rate of recovery may only allow the resource to achieve that level more quickly. For example, if it was possible to eliminate the residual oil in some mussel beds that may still be affecting harlequin ducks, it could speed up their recovery without changing their eventual, long-term population size.

Projects such as creating new salmon spawning or rearing areas have the potential to affect (enhance) long-term population levels. They change the actual number of fish or animals in the long-term population. These options change the degree of recovery.

General Restoration projects may also protect natural recovery and allow it to proceed with a minimum of interference. In this way, they may affect either (or both) the rate or degree of natural recovery. Projects may provide information to allow agencies to manage human use to protect the habitat or to protect the injured resources directly. Examples include redirecting hunting and fishing harvest, or reducing disturbance around sensitive breeding areas. Other protection projects might reduce marine pollution that is stressing a resource or delaying recovery.

The workshop focused primarily on monitoring and research needs for the restoration process. However, two specific general restoration issues were discussed and identified as high priorities. These were cleaning of oiled mussel beds and increased management intensity for commercial and recreational fisheries.

Cleaning Mussel Beds

The continued exposure of injured resources to oil in contaminated mussel beds was previously identified as a high-priority research issue in the nearshore ecosystem. In 1994, the Trustee Council allocated $518,000 (Project 94090) to clean oiled mussel beds in western Prince William Sound. Scientists hope that cleaning the mussel beds will remove an important source of continued oil exposure and thereby start or accelerate recovery of the resources that feed on the mussel beds such as harlequin ducks, black oystercatchers, and sea otters. This restoration project is an example of how research to understand the processes affecting the recovery of injured resources and directed general restoration can be inextricably linked.

Fisheries Management Projects

A variety of restrictive management measures and projects to provide higher resolution of harvest and escapement management have been undertaken since the oil spill. Information on the use of these approaches for restoration of specific resources is included in Appendix B. In 1994 and previous years, the Trustee Council approved a variety of projects to provide stock separation information to allow the Alaska Department of Fish and Game (ADFG), which sets harvest regulations, to vary the timing and location of fishing to minimize harvest of the injured fish runs, particularly salmon. This task typically involves stock separation so that fisheries managers can determine the portion of the catch (at different locations and times) that originates from the different runs. Marking programs and genetic stock identification are examples of management tools for stock separation. This information is beyond that historically gathered by ADFG and allows it to manage fishing to protect the injured runs. Workshop participants recognized the need for increased management resolution for protecting recovery of the injured stocks, while allowing harvests so that commercial and sport fishing services are not further injured. Projects that provide this information for higher management resolution should be defined as general restoration rather than research.

Other Examples of General Restoration Projects

A number of other general restoration projects have been funded by the Trustee Council in 1994. Because the workshop did not discuss general restoration beyond the scope detailed above, no attempt is made here to comment on or prioritize among these projects. They are listed here as examples of approaches to the challenge of active restoration, in order to stimulate discussion of this issue in future workshops.

<u>Lake Fertilization in Coghill Lake</u>. The production of sockeye salmon from Coghill Lake, in western Prince William Sound, declined for reasons unrelated to the oil spill. In 1994, the Trustee Council allocated $324,100 (Project 94259) as part of a continuing program to fertilize the lake to increase production back to its historic levels. Until the recent decline, Coghill Lake was an important salmon run for commercial and sport fishermen in Prince William Sound, and restoring the run will provide natural production to replace that hurt by the spill. The primary benefit to restoration will be to improve the commercial, sport, and subsistence fishing opportunities by enhancing the production of sockeye salmon in Prince William Sound.

<u>Removal of Introduced Predators</u>. In 1994, the Trustee Council allocated $84,000 (Project 94041) to eliminate introduced foxes on three islands just outside the spill area. The foxes are not natural to the islands and remain from abandoned fur-farming operations that began before 1930. Removing foxes that prey on breeding common murres, pigeon guillemots, and black oystercatchers and other seabird resources should result in both immediate and long-term increases in the populations of these resources in the spill area.

Instream Fish Habitat Improvements. The Trustee Council allocated $755,000 (Projects 94139 and 94043) to improve instream habitat for four salmon species, cutthroat trout, and Dolly Varden. The funding will be used to improve instream habitat by constructing bypasses that allow salmon to get past waterfalls to new spawning habitat, by constructing spawning channels, or other techniques to improve habitat and increase the populations of these resources. These projects should result in enhanced production of salmonids to aid recovery of injured commercial, sport, and subsistence fisheries.

Waste Oil Disposal Facilities. In spite of regulations and enforcement actions, a substantial (but unknown) amount of waste oil finds its way into the marine environment. In 1994, the Council approved $232,200 (Project 94417) to fund a pilot program to create waste oil recycling or disposal programs in six small communities in the spill area. The waste oil recycling or disposal facilities will decrease chronic marine pollution from these communities. In this way, the project will minimize the amount of additional oil that is reaching resources injured by the spill. It will protect recovery by minimizing interference from chronic marine pollution from these communities.

Appendix A

WORK GROUP SUMMARY NOTES

Attached are the workshop notes as submitted by the chairpersons of the four Interdisciplinary Work Groups (Marine Mammals, Fish, Birds, and Archaeology), and the three Ecosystem Work Groups (Pelagic, Nearshore, and Uplands). The work group chairperson is in parentheses in the table of contents below.

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Marine Mammal Interdisciplinary Work Group
13 April 1994 - Anchorage, AK

Members of this group included Kathy Frost, ADF&G; Brenda Ballachey, NBS; Jim Bodkin, NBS; Marilyn Dahlheim, NMML/NMFS; Craig Matkin; Bud Antonelis, NMML; Chris Blackburn; David Scheel, PWS Science Center; Martha Vlasoff, Tatitlek; Bob Loeffler, ADEC; and Byron Morris, NMFS.

Broad questions or hypotheses were developed to address marine mammals in PWS in a general sense. Related, more species-specific questions were provided as examples of how these broad hypotheses might be pursued. The group felt that most of these concepts pertained to seabirds and other predators in PWS as well as to marine mammals, but because this was specifically designated a marine mammal working group, the questions were framed relative to marine mammals. Because most of us, and particularly the general public, are more familiar with thinking about ideas and cause and effect relationships as questions rather than as hypotheses, we presented our ideas as questions. A list of these questions is attached, with the species for which the question is relevant in parentheses.

The questions were developed after taking into consideration the recent status of marine mammals in PWS as well as management needs for the species. As part of their daily jobs, many of the scientists in the group must make decisions about these species based on incomplete information and limited historical data with which to put things in context. It is difficult to design a program to facilitate recovery when not enough is known about what constitutes a healthy population.

Background:

Harbor seals in PWS and the northern Gulf of Alaska have been declining for over a decade. The EVOS caused additional mortality in the spill area. In the four years since the EVOS, seal numbers have not shown any indication of recovery. In contrast, seals in southeast Alaska and Canada appear healthy and increasing. The reasons for the decline in the northern Gulf and PWS are unknown, but limited (or changing) availability of prey, particularly forage fishes, has been suggested as a cause for the decline. It is not possible, however, to eliminate other causes such as disease, predation by killer whales, harvest, or take by fisheries, or several of these factors in combination.

Prior to the EVOS, sea otters in PWS had been increasing and their range expanding into new areas of the Sound. Several thousand sea otters died immediately following the EVOS. Furthermore, in the two years following the spill, mortality of prime age adults continued to be abnormally high and juvenile survival was lower in the oiled area than in unoiled eastern PWS. As of 1993, overall numbers of otters in the spill area appear to be increasing, but densities remain low in some affected areas. Adult mortality appears to have returned to normal, but juvenile survival is still lower in the oiled area. It is unknown whether this persistent difference between eastern and western PWS is due to differences in habitat or residual effects of the EVOS.

Several pods of killer whales encountered oil following the EVOS, including AB pod. Thirteen animals were found to be missing from AB pod during 1989-1990. The data are inconclusive about whether this was due to the EVOS or other unknown factors. No calves were born in 1989 or 1990 but several have been born since then, suggesting that AB pod is recovering. Approximately 170 killer whales use PWS on a regular basis. They eat a variety of marine mammals, salmon, and other fishes and squid. It has been speculated that harbor seal numbers are so low that killer whale predation may be significantly affecting the population. The effects on killer whales of recent low returns of pink salmon and herring are unknown.

Sea lions, like harbor seals, are experiencing an ongoing decline in the Gulf of Alaska. Because of this decline, they have been listed as threatened under the Endangered Species Act. Sea lions are seasonal residents of PWS. Major rookeries and haulouts are located in the Gulf. Because of limited historical data for PWS, it could not be determined whether sea lions were affected by the EVOS. Like harbor seals, the reasons for the ongoing decline are unknown, but could include prey availability, disease, predation, or anthropogenic causes. Major, integrated research programs are being conducted by federal and state agencies and universities to investigate the causes of the decline. For this reason, the marine mammal working group did not recommend that the oil spill restoration program fund sea lion studies. However, the group recommended regular exchange of information and coordination between PWS marine mammal and forage fish studies and similar sea lion studies.

The group agreed that harbor and Dall's porpoises may have been impacted by the EVOS, but that the near absence of historical data precludes any quantitative evaluation of this situation.

Marine Mammal Questions

Question 1: How do changes in the availability of prey (natural or spill-related) affect the health and productivity of marine mammals and other higher trophic levels? (HS, SO, KW)

Question 2: How does habitat affect the recruitment, growth, condition, behavior, and survival of marine mammals? (SO, HS)

Question 3: Are populations of marine mammals in PWS genetically distinct from those in other regions of Alaska? (HS, KW)

Question 4: Are the reproduction, growth, survival, and condition of marine mammals similar in years when PWS acts as a lake and years when it acts like a river (or in oiled and unoiled areas)? (HS, SO)

Question 5: Are current declines and lack of recovery by marine mammals caused by disease? (HS, SO)

Question 6: Are current declines and lack of recovery in marine mammals due to anthropogenic causes (fisheries take, subsistence harvest, disturbance)? (HS, SO)

Question 7: Has direct exposure to hydrocarbons and/or ingestion of contaminated prey impacted current or future survival and reproductive success of marine mammals in PWS? (SO, HS)

In addition to the primary questions, the group felt there were several other statements it wanted to make about tasks that should be addressed:

Task 1: Historical data (about marine mammals, seabirds, oceanography, fishes) should be analyzed across species and trophic levels and synthesized to provide better insight into ongoing ecosystem changes.

Task 2: We need to know more about what constitutes important marine mammal habitat in order to effectively protect or manage such areas.

Task 3: Toxicology data collected following the EVOS should be synthesized across species and trophic levels.

Task 4: A database should be maintained to ensure that data about marine mammals and other species in PWS are available to other scientists and to the public.

Several examples of more specific questions that fall under the general questions are:

Question 1:

a) Has the decline in harbor seals in PWS (and the Gulf) occurred primarily because of changes in the availability of prey, particularly forage fishes?

b) Is the recruitment of forage fishes determined by losses of juvenile fishes to predatory marine mammals?

c) Has predation by killer whales caused or exacerbated the harbor seal decline, or is killer whale predation preventing recovery?

d) How do the diets of killer whales differ by area, between pods, or between resident and transient groups?

e) Are oil-related changes in prey availability affecting survival rates of juveniles?

f) Are oil-related changes in prey availability limiting re-occupation of sea otter habitat?

Question 2:

a) Are habitat differences between eastern and western PWS, rather than oiling history, causing reduced survival of juvenile sea otters in the western Sound?

Question 3:

a) Do harbor seals in PWS constitute a genetically distinct population from seals in southeast Alaska, and are they similar to seals in the Gulf?

b) Are sea lions in PWS genetically intermediate between those in the Gulf and in southeast?

c) Are resident and transient killer whales in PWS genetically distinct?

SUMMARY OF FISH INTERDISCIPLINARY WORK GROUP DISCUSSIONS

The Fish IWG was charged with considering recovery monitoring, research, and general restoration priorities for injured fish resources which were not recovering or whose recovery was unknown. We attempted to identify the priority issues for the injured resources, and develop hypotheses that could be used to guide the solicitation of projects for the 1995 Work Plan. Recovery monitoring objectives and strategies for fish resources were provided directly to Byron Morris for inclusion with the comprehensive compilation of recovery monitoring for injured resources, and are not included here. This summary will focus on the research and general restoration issues we identified.

Before considering resource-specific research issues, the IWG developed a framework for posing the pertinent research question: Why are injured resources not recovering? We developed the following framework for factors that could be influencing recovery.

1. Ecosystem Processes
    - A. Oceanography/Meteorology
    - B. Trophic Interactions:
        - a. Is it food?
        - b. Is it predation?
        - c. Is it competition?
    - C. Variability or limitations in productivity of natal habitats
2. Ecotoxicology: Is it oil?
    - A. Histopathological
    - B. Genetics
3. Other Human Activities
    - A. Resource Exploitation (Management)
    - B. Enhancement
    - C. Upland Development
4. Disease

We then developed a list of priority issues and associated hypotheses relating to the recovery of the six species of fish that are on the list of injured resources. These issues and hypotheses are summarized below; the number following each hypotheses refers to the framework outline on the preceding page.

All of these species are important commercial and sport fishing resources. As such, increased management resolution has been necessary to effectively manage the resources so that harvest opportunities can continue to the extent possible without negatively impacting the recovery of damaged populations. These types of management requirements are identified below for several of the injured resources. The IWG felt that additional increments of management effort beyond the normal agency requirements should be considered general restoration projects.

Sockeye Salmon

Issue 1. Reduced production of sockeye salmon from lakes due to adult overescapement in 1989. A better understanding of trophic interactions in sockeye rearing lakes is necessary to restore depressed smolt production capacity.

> Hypothesis: Trophic interactions are limiting recovery of injured sockeye salmon populations. (1.B.)

Issue 2. Declining sockeye salmon production may be a result of natural or anthropogenic alteration of natal habitats.

> Hypothesis: The recovery of injured sockeye salmon populations is limited by alterations of natal habitats. (1.C. and/or 3.C.)

Issue 3. How do we effectively manage harvest of depressed sockeye salmon populations to ensure restoration?

> Hypothesis: Stock composition in mixed stock fisheries (involving injured and uninjured sockeye populations) can be determined to effectively allow harvest of uninjured stocks while protecting injured stocks. (General Restoration to ensure escapement of damaged populations)

Pink Salmon

For pink salmon, several hypotheses are listed that involve ecosystem processes and the potential for interactions of wild and hatchery fish. The IWG discussed the difficulty of defining actual causative mechanisms of variations in abundance of populations by correlative or process-modeling approaches. We felt that large-scale manipulations of hatchery releases, involving annual and intra-annual variations in the numbers, location, time, and size of fish released, could be a powerful tool to explicitly test for both wild/hatchery stock interactions and mechanisms that influence or limit carrying capacity for pink salmon in Prince William Sound.

Issue 1. Lack of recovery of pink salmon in Prince William Sound.

> Hypothesis: Lack of recovery of pink salmon production is the result of natural variability in carrying capacity in the marine environment. (1.A.,1.B.)
>
> Hypothesis: Decline in pink salmon production is due to continuing impacts of oil exposure. (2.A.,2.B.)
>
> a. Continued elevated egg mortality is caused by heritable genetic damage from oil-exposed parents. (2.B.)
> b. Outbreeding depression was caused by oil-induced straying. (2.B.)
> c. Reduced egg viability in oiled streams is due to reduced viability of gametes in oil-exposed fish. (2.A.)
>
> Hypothesis: Decline is due to adverse wild/hatchery stock interactions. (3.B.)

Issue 2. Declining pink salmon production may be a result of natural or anthropogenic alteration of natal habitats.

> Hypothesis: The recovery of injured pink salmon populations is limited by alterations of natal habitats. (1.C. and/or 3.C.)

Issue 3. How do we effectively manage harvest of depressed pink salmon populations to ensure restoration?

> Hypothesis: Stock composition in mixed stock fisheries (involving injured and uninjured pink populations) can be determined to effectively allow harvest of uninjured stocks while protecting injured stocks. (General Restoration to ensure escapement of damaged populations)

Herring

Issue 1. Lack of recovery and precipitous decline in spawning biomass of Prince William Sound herring.

> Hypothesis: Lack of recovery of herring production is the result of natural variability in carrying capacity in the marine environment. (1.A.,1.B.)
>
> Hypothesis: Decline in herring production is due to continuing impacts of oil exposure. (2.A.,2.B.)
>
> Hypothesis: The advection of larval herring from the nursery areas reduces the recruitment of herring to PWS. (1.A.)
>
> Hypothesis: Winter conditions limit survival or reproductive success of herring. (1.B.)
>
> Hypothesis: Viral hemorrhagic septicemia (VHS) is causing the current losses of PWS herring stocks. (4.)

Issue 2. Declining herring production may be a result of natural or anthropogenic alteration of natal habitats.

> Hypothesis: The recovery of injured herring populations is limited by alterations of natal habitats. (1.C. and/or 3.C.)

Issue 3. How do we effectively manage harvest of depressed herring populations to ensure restoration?

> Hypothesis: Stock composition in mixed stock fisheries (involving injured and uninjured herring populations) can be determined to effectively allow harvest of uninjured stocks while protecting injured stocks. (General Restoration to ensure escapement of damaged populations)

Cutthroat Trout and Dolly Varden

Issue 1. How do we effectively manage harvest of impacted cutthroat trout and Dolly Varden populations to ensure restoration? (General Restoration to ensure escapement of damaged populations)

Conservative sport fish management regulations have been implemented to reduce exploitation of impacted populations. These management measures will be continued until restoration objectives have been met. Recovery status of these resources is unknown. No specific research priorities have been identified for these species.

Rockfish

Issue 1. Extent of injury and recovery objectives for this resource remain undetermined.

Synthesis of NRDA studies and other data on PWS rockfish is needed to determine if a recovery objective can and should be defined, and to recommend a monitoring strategy to determine the status of the resource.

April 20, 1994

Memorandum

To: Molly McCammon, EVOS Restoration Office

From: David Irons, Interdisciplinary Bird Group Leader

Subject: List of Hypotheses Assembled by the Bird Group Concerning the Recovery of Injured Bird Species

Attached is a list of hypotheses that were generated and agreed upon by the bird group concerning the factors that may limit the recovery of injured bird species. Also attached is a matrix of injured species and parameter that was affected.

Injured Bird Species and Parameters Affected for Each Species

Parameter Affected	Common Murre	Harlequin Duck	Marbled Murrelet	Pigeon Guillemot
Oiled Population	X	X		X
Total Population	X		X	X
Oiled Carcasses	X	X	X	X
Production	X	X		X
Over Winter Survival	X			
Distributional Changes	X			

Below is a list of potential factors that may limit the recovery of injured bird species. For each factor, a hypothesis can be generated. For example: Food availability limits the recovery of injured species.

1. Food Limitation

2. Predation

3. Oil Toxicity

4. Human Disturbance

5. Nest Site Limitation

6. Disease

Below are hypotheses addressing the mechanisms by which each factor could limit recovery.

FOOD LIMITATION

A. Climatically driven ecosystem shift changed composition of fish species, which affects PWS population levels, productivity, over winter survival, and distributional changes of injured species.

B. Increasing numbers of salmon smolt released by fish hatcheries caused decreases in number of forage fish, which affects PWS population levels, productivity, over winter survival, and distributional changes of injured species.

C. The oil spill affected prey populations, which affects PWS population levels, productivity, over winter survival, and distributional changes of injured species.

D. The River/Lake System controls prey populations, which affects PWS population and productivity of injured species.

PREDATION

A. Numbers, distribution, or behavior of mammalian or avian predators has changed, which affects PWS populations and productivity of injured species.

B. Vulnerability of target species to predation has increased, which affects PWS population and productivity of injured species.

OIL TOXICITY

A. Ingestion of oiled foods decreased bird productivity, which affects the PWS population, the oiled population, and productivity of injured species.

B. Oiling of eggs decreased hatch-ability, which affects the PWS population, the oiled population, and productivity of injured species.

C. Oil ingestion/contact increased natural mortality, which affects the PWS population, the oiled population, and productivity of injured species.

D. Oil spill mortality changed social behavior, habitat use, and vulnerability to predators, which affects the PWS population, the oiled population, and productivity of injured species.

HUMAN DISTURBANCE

A. Increased boat traffic affects productivity of injured species.

B. Gill net mortality affects the PWS populations and productivity of injured species.

NEST SITE LIMITATION

A. The number of nest sites has been reduced by logging, which affects the PWS population, the oiled population, and productivity of injured species.

B. Habitat quality differs between oiled and unoiled areas, which affects the oiled population and productivity of injured species.

DISEASE

A. Pathogens increased winter mortality which affects productivity, over winter survival, and distributional changes of injured species.

RESEARCH PRIORITIES FOR RESTORATION MEETING
INTERDISCIPLINARY WORK GROUP
ARCHAEOLOGY
April 13-15, 1994
Anchorage, Alaska

Report of Archaeology Work Group meeting April 13 and 14.

Participants:

Ted Birkedal
National Park Service
Anchorage

Judy Bittner
Department of Natural Resources
Anchorage

Fred Clark
U.S. Forest Service
Anchorage

Linda Yarborough
U.S. Forest Service
Anchorage

Robert Shaw
Department of Natural Resources
Anchorage

Martha Vlasoff
Tatitlek

Background: Cultural Research as a Tool to Provide Long-Term Comparative Data on Ecosystems in the *Exxon Valdez* Area of Effect:

If we are to understand how the *Exxon Valdez* oil spill event has altered or otherwise affected present-day nearshore and upland ecosystems and their constituent subsystem components, it is imperative to have a basis for comparison, a point of reference from which to identify and measure changes that might be directly or indirectly attributed to the spill. Ecosystems are not static clockworks, but dynamic systems in a constant state of change and, as emphasized by the paleoecologist E. C. Pielou, they are always characterized by a greater or lesser degree of disequilibrium. Thus, the base for informed comparison is a moving target, not time-bound portraits of the ecological systems of the Gulf of Alaska as these appeared in a brief snapshot of time on the eve of the oil spill.

How then can we obtain this historical perspective on the ecosystems of the region? One promising source of this long-term ecological data is the archaeological record of the area. Archaeological sites may be likened to a vast array of fortuitous environmental sampling stations extending back into time. For a period of at least 6000 years, humans along the coast launched out from their settlements and camps and sampled the world about them in their daily subsistence pursuits. The accumulated debris from this massive, systematic environmental sampling effort has been conveniently concentrated in the archaeological sites. This record, though often coarse-grained in terms of precise dates, may offer answers to some of the questions posed by contemporary ecosystem scientists who are trying to discriminate between changes that have links to the oil spill and those that represent fluctuations in natural systems over time.

Another source of long-term data may be found through ethnographic and historical research. Native Alaskans over the past millennia have accumulated a rich storehouse of information about the local environment, and though much of this knowledge has been lost of late, much still survives. The survival of coastal Native peoples has always depended on accurate, empirical observations about the world and its fickle environment. Historical archives and the memories of non-Native Alaskans also may offer valued information on the operation of the environment in the past.

The potential of these archaeological, ethnographic, and historical sources to provide answers to key questions about long-term ecosystem change and stability in the region should be explored. That would in turn provide the understanding necessary to determining what changes in the environment are necessary to attain restoration. If findings demonstrate that this potential can be realized in a timely manner through reasonable outlays of funds and effort, then follow-up research programs to compile and analyze the data could be developed and implemented in subsequent years.

Hypotheses:

The Archaeology Work Group meet on April 13 and developed the following hypotheses:

<u>Hypothesis 1</u>: Cultural Dynamics: Subsistence changes have caused major cultural shifts in the spill area.

Background: The EVOS has modified the ecosystem on which subsistence use in the spill area is based.

Method: Look at the archaeological record and collect traditional knowledge to correlate cultural changes with major ecosystem shifts, e.g., short-term changes (volcanic eruptions, 1964 Earthquake, EVOS) and long-term changes (climatic changes).

Hypothesis 2: Vandalism: Vandalism related to the *Exxon Valdez* oil spill will increase over time in specific high artifact-yield sites.

Method: Identify potential target sites, which include already damaged sites and undamaged sites with potential high interest to vandals. Monitor vandalism of these sites over time. Develop cooperative community based protection programs to decrease vandalism.

Hypothesis 3: Cultural Ecological Research: Archaeological, ethnographic and historic data can produce an informed comparative baseline for EVOS ecosystem studies. Existing archaeological collections may contain faunal/floral samples which will provide critical insights into specific ecosystem problems. Once assessed, the existing data should be supplemented by specific site excavation designed to fill in data gaps.

Method: Paleoecological research at selected archaeological sites. Ethnographic and ethnohistorical research. Historical archival research.

Pelagic Ecosystem Session:

The biologists participating in the Pelagic Ecosystems session April 14 initially organized their discussions around:

> Food -- Predation -- Oil Toxicity -- Disease -- Disturbance (human) -- Habitat Limitation -- Ocean Climate

During the discussion, the organizing categories evolved somewhat, and polls were taken to "determine" relative significance as viewed by the group. The poll ordered the expanded topics list roughly as follows:

> Food
> Oceanography
> Monitoring index species
> Predator/prey relationships
> Oil effects
> Genetics
> Habitat
> Hatcheries
> Harvest prediction
> Anthropogenic (including archaeology) factors
> Disease

Archaeologists Bob Shaw and Linda Yarborough attended the Pelagic sessions. They emphasized archaeology as a source of data relating to several areas of concern, requesting that the biologists specifically consider the information potential of archaeological data for their projects. Both Shaw and Yarborough made short specific suggestions as examples of inquiries they felt might be productive.

Shaw suggested examining faunal remains of increasing age (based on archaeological stratigraphy and radiocarbon dating) to determine if oil from natural petroleum seeps along the Alaskan Pacific coast became incorporated into the prehistoric food chain and were deposited in bones of animals. The group showed little interest because they thought that such impacts would not show up.

Yarborough suggested genetic studies of faunal materials from archaeological sites to determine interrelationships of animal populations through time, perhaps up to 4,000 years. Faunal analysis of archaeological materials will also give information on relative abundance of species at specific localities through time. There was light interest in animal population genetics among the biologists, and they showed equally light interest in the use of archeological samples for genetic studies.

The archaeologists asked the group to continue to consider the potential to use archaeological data as they develop individual projects. Archaeology, ethnography/traditional knowledge studies, and historical research are potential sources of long-term comparative data that could aid understanding of current ecosystems in the oil spill area.

Nearshore Ecosystem:

The participants organized their discussions around three areas of focus: population, trophics, and toxicity.

It was agreed that scientists should be able to request data collection without hypothesis. Long-term baseline data collection and monitoring are needed to be able to answer questions in the hypotheses. Disallowing baseline data collection creates a risk of premature closure on scientific approaches.

Both biological and nonbiological processes limit recovery in nearshore ecosystem.

The group developed seven hypotheses, two of which covered humans and their place in the environment. They were cultural and archaeological issues and/or to which archaeological data could contribute to the understanding through time of the ecosystem dynamics.

Hypothesis 4: EVOS-induced changes in populations of benthic prey species have influenced the recovery of benthic foraging predators and affected human (subsistence?) use. (Note: "Subsistence" went in and out as an adjective. Martha Vlasoff wants it in, but some thought this is also applied to commercial fisherman, etc. It was difficult to sort out because some Natives do both commercial and subsistence fishing and hunting. For example, herring, and in the case of harbor seals, the meat is subsistence only, but skins can be sold commercially. The injured species relating to humans are herring and harbor seals.)

Hypothesis 5: EVOS-induced changes in populations of top predators and/or human users have influenced the recovery of EVOS-injured benthic prey populations. (Note: Again

Martha Vlasoff wanted "subsistence" to be a prominent adjective so it would refer to "human subsistence users". The injured species of relevance here are herring and harbor seals.)

Summary:

In summary, subsistence/human use questions became imbedded in the hypothesis of the Nearshore Ecosystem groups (H.4 and H.5). Archaeology, ethnography and history, on the other hand, do not have a separate existence under Pelagic (water dwelling) hypotheses or benthic (bottom dwelling) hypotheses. Here they become potential tools for understanding past ecosystems, essentially, contributing to paleoecological research. However, archaeological resources, per se, since they do not fit into ecosystem research frameworks like herring and harbor seals, do need a separate section of their own. Discussions at the workshop by EVOS Trustee Director of Operations indicated that a separate section on the restoration of archaeological resources is therefore required. The separate archaeological resources section would include discussion of the implementation of a Community Protection Plans Project and its status, and that the preliminary result from the initial planning phase, available in October 1994, would provide guidance to future years. Secondly, this section would address projects for mitigating (restoring) injured intertidal beach sites in the oil spill area. They would seek replacement data for injured sites by recovering and assessing comparable age data at untreated/unoiled sites.

PELAGIC ECOSYSTEM WORK GROUP

14 April 1994 - Anchorage, AK

The Pelagic Work Group consisted of approximately 30 people from a variety of disciplines. There were scientists familiar with seabirds, marine mammals, forage fishes, and oceanography. I do not have a complete list of the working group, but it included Kathy Frost, ADF&G; Marilyn Dahlheim and Bud Antonelis, NMML; Brenda Ballachey and Scott Hatch, NBS; Dave Irons, FWS; David Salmon and David Scheel, PWSSC; Kate Wynne, Sea Grant; Ted Cooney, Don Schell, A. J. Paul, and Brenda Norcross, Univ. of Alaska; Jeep Rice, Bruce Wright, Alex Wertheimer, Byron Morris, Ken Krieger, NOAA; Chris Blackburn; and ????

After many repeated tries to find a focus, the group agreed that, in general, questions could be asked as follows:

Is it trophics (food availability or predation)?
Is it physical/oceanographic features (decadal or nutrient cycles)?
Is it oil?
Is it anthropogenic?
Is it disease?
Is it habitat?

From these six broad questions or topics, the group then developed 12 questions which it felt addressed the priority issues in the pelagic ecosystem. After several false starts and extended discussion about direction, the group agreed that everyone at the table would suggest a question they considered of key importance. If someone's question had already been identified, the individual passed. At the end of this process, the group identified the 12 questions listed below. Following the initial listing of questions, each person was asked to name his/her top three priorities. The questions below are listed in priority order. The third step in the process was to discuss the applicability of each question to the six injured but not recovering species and to rate it as High, Medium, or Low priority for the particular species.

PELAGIC ECOSYSTEM QUESTIONS

1) Is food limiting, i.e., are changes in the availability of prey (natural or spill-related) affecting the recovery of injured species?

2) Are oceanographic cycles (decadal temperature cycles, nutrient cycles, etc.) limiting the availability of prey to higher trophic level consumers?

3) How can key ecosystem components be most effectively monitored?

4) Is predation limiting recovery of injured resources?

5) Is oil still affecting injured species, either through residual effects from prior exposure, continuing exposure, or ingestion of contaminated prey?

6) Is the genetic population structure of injured species adequately known?

7) Is the availability of suitable habitat limiting recovery?

8) Does the release of hatchery salmon affect the food supply of injured species?

9) Are better tools (predictive or other) available to manage the harvest of injured species?

10) Are anthropogenic effects, such as harvest, disturbance, or fisheries affecting recovery?

11) Is disease affecting recovery?

12) Can the analysis of archaeological samples provide useful baseline information about species composition relative to climate or genetic variation over time of injured resources?

1) Is food limiting, i.e., are changes in the availability of prey (natural or spill-related) affecting the recovery of injured species?

Since about the mid-1970s, a variety of species of marine mammals and seabirds in the pelagic ecosystem have been declining in the northern Gulf of Alaska and PWS. These include harbor seals, sea lions, kittiwakes, and murres. In contrast, species utilizing nearshore habitats, such as sea otters and sea ducks, have been stable or increasing during the same time period. This had made biologists think that differences inherent in the food webs of these species may be responsible for differing trends. However, the mechanisms of the declines are unknown. In the case of seals or sea lions, it may be poor juvenile survival. In the case of seabirds, it may be poor survival of chicks.

All of the declining species rely at least in part on forage fishes such as herring, capelin, sandlance, smelt, and juvenile pollock for food. During the approximately 20 years that marine mammals and seabirds have been declining, the estimates of pollock biomass (based on modelling exercises since no comparable trawl survey data exist prior to the mid-1970s) have increased substantially. The biomass of other species of forage fishes may have decreased, but there are almost no data on these species. The northern Gulf has experienced a warming trend during the same time, which may have affected the abundance of these forage fishes.

More specific information is needed about the diet composition of marine mammals and seabirds; seasonal and annual variability in diet; age-specific differences in diet; and the energetic values of different prey. In addition, information is badly needed on non-commercial forage species (particularly forage fishes and squid) for which there are almost no data on regional abundance or trends in abundance.

2) Are oceanographic cycles (decadal temperature cycles, nutrient cycles, etc.) limiting the availability of prey to higher trophic level consumers?

As long-term databases and increasingly sophisticated computers make complicated analyses of historical data possible, it is becoming evident that some changes in populations of fishes, birds and marine mammals may be related to long-term cycles (decades or more). In order to detect the influence of such cycles on higher trophic levels, it is necessary to maintain a long-term database and to monitor key oceanographic parameters on an ongoing basis. Without such data, it will not be possible to evaluate the effects of climatic changes on the biota.

Because climate-induced cycles may be very long term, their effects may be subtle and therefore not obvious to biologists working with short-term data sets. This increases the likelihood that causes for increases or decreases in species abundance may be falsely attributed to an unrelated but plausible cause.

Data on temperature and chlorophyll may be useful in predicting zooplankton success, and therefore an indicator of food availability to young fishes which are in turn prey of seabirds and marine mammals.

3) How can key ecosystem components be most effectively monitored?

Any detailed understanding of ecosystems requires long-term data sets with which to evaluate normal variation in the distribution and abundance of key ecosystem components. It is not possible to evaluate status and trends of populations without historical perspective on changes in distribution and abundance of the species and their predators and prey. This does not mean that every species at every trophic level must be monitored. Key ecosystem components should be selected from an interdisciplinary perspective. This might include monitoring key oceanographic parameters such as temperature and chlorophyll, zooplankton standing stock in particular areas, and key species or seabirds and marine mammals. Whenever possible, methods should be developed to index trends in abundance, rather than conduct extensive whole-population counts.

A prime example of limitations placed on scientists by the lack of historical data is the ongoing decline in harbor seals, sea lions, and several species of seabirds. Food limitation in some form is considered the most likely cause of these declines. However, there are almost no quantitative historical data on the distribution and abundance of important forage fishes. Scientists must guess about abundance of species based on indirect indicators such as relative frequency in stomachs.

4) Is predation limiting recovery of injured resources?

Recent declines in some fishes (such as pink salmon and herring) and marine mammals (harbor seals and sea lions) may have significantly changed the availability of prey to top predators and caused them to prey more on other species. For example, when pink salmon are less numerous, eagles may prey more heavily on nesting seabirds. Reduced availability of salmon and herring may cause killer whales to prey more heavily on marine mammals. Furthermore, since numbers of seals and sea lions are greatly reduced, predation may have a far greater impact on the population.

5) Is oil still affecting injured species, either through residual effects from prior exposure, continuing exposure, or ingestion of contaminated prey?

6) Is the genetic population structure of injured species adequately known?

In order to assess to significance of mortality caused by events such as the EVOS, it is necessary to understand what constitutes a population or stock. One of the main questions asked following the EVOS was whether there were population-level effects. Without an understanding of how PWS animals relate to those in adjacent areas - e.g., whether they are genetically distinct and form different populations or stocks - it is not possible to address this questions. For example, harbor seals are declining in PWS and the Gulf, but not in southeast Alaska. Do they belong to a different population (Are they genetically distinct?) or are they indistinguishable from seals in southeast, suggesting regular intermingling?

Killer whales were found missing from resident AB pod in PWS. Are resident pods in PWS genetically distinct from transient pods, suggesting little or no mixing, or are they similar? Not enough is known about the stock characteristics of herring to determine whether they should be managed as one stock or more than one.

7) Is the availability of suitable habitat limiting recovery?

It is possible that persistent effects of oiling have affected the suitability of spawning habitat for herring and pink salmon in PWS.

8) Does the release of hatchery salmon affect the food supply of injured species?

Hatcheries have released millions of salmon into the PWS and Gulf of Alaska ecosystem over the last decade. At all stages of their lives, these salmon consume significant quantities of either zooplankton or small fishes. They may compete directly with wild salmon, other fishes, seabirds, or marine mammals for this prey. Releases of hatchery fish may attract predators, which then also prey on other species.

9) Are better tools (predictive or other) available to manage the harvest of injured species?

10) Are anthropogenic effects, such as harvest, disturbance, or fisheries affecting recovery?

Effects of human activities may impair the ability of injured species to recover. For example, harbor seal numbers are greatly reduced because of the ongoing decline, which was exacerbated by additional spill-related mortality. At this reduced level, the population may be impacted by any additional mortality, such as that caused by subsistence harvest or take associated with fisheries. Marbled murrelets were also reduced by the spill. They nest in upland forests, which are currently being logged in some areas of PWS. This could affect nesting success and the ability of murrelets to recover.

11) Is disease affecting recovery?

In both 1992 and 1993, spawning herring in PWS were affected with viral hemorrhagic septicemia. This disease is often associated with stress. It has been suggested that herring may be stressed by ongoing effects of the spill and that this stress resulted in appearance of viral disease.

12) Can the analysis of archaeological samples provide useful baseline information about species composition relative to climate or genetic variation over time of injured resources?

Table 1. Twelve important questions regarding the pelagic component of the Prince William Sound ecosystem, and their priority for six injured species that are not recovering.

Question/Issue	Pink Salmon	Herring	Harbor Seals	Murres	Marbled Murrelets	Pigeon Guillemots
Is food limiting?	Medium	High	High	High	High	High
Do oceanographic cycles limit food availability?	High	High	Medium	High	High	High
How can key ecosystem components be most effectively monitored?	High	High	High	High	High	High
Is recovery limited by predation?	High	High	High	High	High	Medium
Is oil still affecting injured species?	High	High	-	-	-	Medium
Is genetic stock structure adequately known?	Medium	Medium	Medium	-	-	-
Is habitat limiting recovery?	Low	Medium	-	-	-	-
Do hatchery salmon affect food supply?	High Low	Low	Low	Low	Low	
Are better predictive tools needed to manage?	High	High	Low	-	-	-
Are anthropogenic effects limiting recovery?	Low	Low	High	-	Medium	Low
Is disease affecting recovery?	-	High	Medium	Low	-	-
Can archaeological samples provide useful information about injured resources?	Low	Low	Low	Low	Low	Low

NEARSHORE MARINE ORGANISMS AND SEDIMENTS AND THE NEARSHORE MARINE ECOSYSTEM WORK GROUP

Report on the results of the meeting of the Nearshore Marine Organisms and Sediments Work Group and the Nearshore Marine Ecosystem Work Group. 13-14 April, 1994, Anchorage Alaska.

Submitted by J. Bodkin

Summary **Seven hypotheses were developed according to their potential for describing the processes responsible for limiting recovery in nine nearshore groups of EVOS-injured resources. Prioritization of hypotheses differs among injured resource groups. Baseline data on abundance and distribution of plants and animals and environmental conditions are lacking for the nearshore ecosystem.**

On 13 April, 1994 an interdisciplinary group of scientists representing **nearshore organisms and sediments** met to identify strategies, research approaches and testable hypotheses for addressing the question "what processes are limiting recovery of *Exxon Valdez* oil spill (EVOS) injured resources?" Primary participants in the group included J. Bodkin (NBS), T. Collier (NMFS), T. Dean (CRA), D. Esler (NBS), R. Highsmith (UAF), A. Hooten, G. Irvine (NBS), C. O'Clair (NMFS), D. Rosenberg (ADFG), J. Short (NMFS), and M. Stekoll (UAF). J. Bodkin was selected to chair the working group and serve as representative to the Interdisciplinary Coordinating Committee. Community components represented in the group included plants, invertebrates, birds, mammals, and environmental hydrocarbons.

The nearshore organisms and sediments group considered two factors in assigning importance to resources that comprise the **Nearshore Marine Ecosystem**. One was ecological importance and the other was the status of the resource relative to EVOS-induced injury and recovery. The subset of resources listed under both categories included more than 30 species of plant, invertebrate, fish, bird, and mammal. No consensus on how to best address the question of resource recovery was reached on 13 April in our allotted time. Each participant was asked to consider the question and develop additional hypotheses for consideration on 14 April. Hypotheses 1-6 (below, as modified) were accepted by consensus on 14 April a.m. as potentially useful in addressing the question of why a resource may not be recovering from the EVOS.

On 14 April a **Nearshore Marine Ecosystem Work Group** met to select and prioritize hypotheses that would best address the question of what processes are limiting recovery of injured resources. Primary participants in the group were B. Ballachey (NBS), T. Birkedal (NPS), J. Bittner (ADNR), J. Bodkin, (NBS), T. Collier (NMFS), T. Dean (CRA), D. Esler (NBS), A. Hooten, G. Irvine (NBS), C. O'Clair (NMFS), S. Patten (ADFG), S. Rice (NMFS), T. Rothe (ADFG), D. Rosenberg (ADFG), D. Schmidt (ADFG), R. Spies (AMS),

M. Stekoll (UAF), M. Vlasoff (Tatitlek) and J. Wilcox (ADFG). J. Bodkin chaired the meeting. The six hypotheses formulated by the nearshore organisms and sediments working group were presented to the Nearshore Ecosystem Work Group and accepted (as modified below) by consensus with the addition of a seventh hypothesis. The seventh hypothesis was added to address physical processes in structuring nearshore communities.

Hypotheses (Table 2 column headings in parentheses)

H_0 1. The EVOS-induced changes in populations of dominant competitors and resident predators in the nearshore region are limiting recovery of benthic communities. (Competition/predation hypothesis)

H_0 2. Recovery of nearshore resources damaged by EVOS is limited by recruitment processes. (Recruitment)

H_0 3. Initial and/or residual EVO in benthic habitats has a toxicological effect limiting the recovery of benthic communities. (Direct toxicity)

H_0 4. EVOS-induced changes in populations of benthic prey species have influenced the recovery of benthic foraging predators and affected subsistence use. (Limited prey, bottom up perspective)

H_0 5. EVOS-induced changes in top predators and/or human use have influenced the recovery of EVOS-injured benthic prey populations. (Predation, top down perspective)

H_0 6. Initial and/or residual EVO on benthic habitats and in or on benthic prey organisms has had an effect on the recovery of benthic foraging predators. (Indirect toxicity)

H_0 7. Physical processes limit the recovery of nearshore ecosystems. (Physical limitations)

Following identification of the seven hypotheses, the group identified four potential mechanisms that may be responsible for limiting recovery in the Nearshore Marine Ecosystem. We then identified in the following matrix (Table 1) those hypotheses that might prove relevant in testing each of the four mechanisms.

Table 2. Hypotheses potentially relevant for testing mechanisms responsible for limiting recovery

Mechanism	Relevant Hypotheses
Oil (ecotoxicology)	3 & 6
Trophic Interactions	1, 2, 4 & 5
Physical Factors (nutrients, light, temp. salinity, larval transport...)	7
Structure (physical or biological)	2 & 4

The Nearshore Ecosystem Work Group concluded that there was generally a lack of baseline data available for the nearshore ecosystem that might be comparable to fisheries harvest, meteorological, oceanographic or biological data available for the pelagic ecosystem. The group recommended that projects designed to understand processes limiting recovery be integrated into a process for collection of baseline data relevant to the nearshore ecosystem. Baseline data should include distribution and abundance of nearshore plants and animals, physical and environmental data, and archeological, ethnographic/traditional and historical data on the nearshore ecosystem.

Following acceptance by the group, we discussed the task of prioritizing the seven hypotheses. Our attempt at prioritizing consisted of developing a matrix (Table 3), listing injured resources in one column, each of the seven hypotheses as column headings and classifying the potential of a particular hypothesis to address the question of recovery for classes or species of injured organisms.

Table 3. Which hypotheses are likely the most important approach to these resources?

Resource	Comp./ Pred. H_1	Recruit. H_2	Direct Tox. H_3	Limited Prey H_4	Pred. H_5	Indir. Tox. H_6	Phys/ lim. H_7
Salmon	-	L	H	L	pred - prey L	-	H
Herring	-	L	L	L	pred - prey H	-	H
Sea Otters	L	L	L	H	-	H	L
Sea Ducks	L	H	L	H	-	H	L
Sea Bird	-	H	PGuil L	H	-	-	L
Shore Bird	-	-	L	L	-	H	L
H. Seal	-	L	-	-	L	-	L
Intertidal Organism	H	H	L	L	H	L	H
Subtidal Organism	H	H	L	L	H	L	H

- = not relevant, L = low potential, H = high potential

Following development of Table 3, it became obvious that for a suite of organisms as diverse as those injured in the nearshore ecosystem, prioritizing hypotheses across grouping of organisms would prove inappropriate. Review of Table 3 suggests marked differences in those processes that regulate the population dynamics of many of the groups of injured resources. Table 3 may be considered as prioritizing those processes within each group of injured resources that may be affecting recovery.

UPLANDS ECOSYSTEM WORK GROUP
22 April 1994 - via conference call

The Uplands Ecosystem Work Group summary information was not available in time for inclusion in this Proceedings.

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Appendix B

DRAFT RESTORATION OBJECTIVES AND STRATEGIES BY RESOURCE AND SERVICE *

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* This is Appendix A in the Invitation to Submit Restoration Projects

Introduction

For each resource or service injured by the oil spill, the *Draft Restoration Plan* identifies strategies to accomplish recovery. The appendix begins by summarizing those strategies. The *Draft Restoration Plan* will be distributed for public review June 18 through August 1, 1994. Thus, the Final Restoration Plan may change some of the strategies summarized in this appendix.

In the remainder of the appendix, resources and services injured by the oil spill are listed alphabetically. For each resource and service, the appendix first lists the recovery status -- a brief description of the current condition of the resource or service. That is followed by the objective — the definition of recovery for that resource or service. It is a measurable definition of what condition the restoration program should accomplish. Any restoration project should help the restoration program reach those objectives (i.e., to accomplish recovery for one or more injured resources or services).

Finally, the appendix lists monitoring, research, and general restoration strategies identified by the workshop. The strategies in this appendix are preliminary and have not been subject to further scientific, legal, or policy review. However, they provide the best current indication of 1995 restoration needs. Also, there is considerable duplication in this appendix, because many resources have similar monitoring, research, or general restoration strategies.

Strategies for Achieving Restoration

The *Draft Restoration Plan* (November 30, 1993) outlines strategies to accomplish recovery. This section of the appendix summarizes those strategies. For more information, see the *Draft Restoration Plan,* especially Chapter 4.

Restoration Strategies from the *Draft Restoration Plan*
Part A. Biological Resources

Biological Resources	Primary Restoration Strategy (from *Draft Restoration Plan*)
Recovering Resources Bald eagle Black oystercatcher Killer whale Sockeye salmon at Red Lake*	***Primary Restoration Strategy*** • Rely on natural recovery • Monitor recovery • Protect injured resources and their habitats
Resources Not Recovering Common murre Harbor seal Harlequin duck Intertidal organisms Marbled murrelet Pacific herring* Pigeon guillemot Pink salmon* Sea otter Sockeye salmon (Kenai & Akalura Systems)* Subtidal organisms	***Primary Restoration Strategy*** • Conduct research to find out why these resources are not recovering • Initiate, sustain, or accelerate recovery • Monitor recovery • Protect injured resources and their habitats
Recovery Unknown Clams* Cutthroat trout Dolly Varden trout River otter Rockfish	***Primary Restoration Strategy*** • Rely on natural recovery • Monitor recovery • Protect injured resources and their habitats

* These resources are also important for subsistence or commercial fishing. For these resources, waiting for natural recovery may significantly harm a community or industry, and the strategies for subsistence or commercial fishing also apply (See Part C of the table.).

Part B. Other Resources

Other Resources	Primary Restoration Strategy (from *Draft Restoration Plan*)
Archaeology	***Primary Restoration Strategy*** • Repair spill-related injury to archaeological sites and artifacts • Protect sites and artifacts from further injury and store them in appropriate facilities • Protect injured resources and their habitats
Designated Wilderness Areas	***Primary Restoration Strategy*** Any restoration strategy which aides recovery of injured resources, or prevents further injuries will assist recovery of designated wilderness areas. No strategies have been identified which benefit only designated wilderness areas without also addressing injured resources.

Part C. Services

Services	Primary Restoration Strategy (from *Draft Restoration Plan*)
Commercial Fishing	***Primary Restoration Strategy*** • Promote recovery of commercial fishing as soon as possible • Protect commercial fish resources as soon as possible • Monitor recovery
Recreation and Tourism	***Primary Restoration Strategy*** • Preserve or improve the recreational and tourism values of the spill area • Remove or reduce residual oil if it is cost-effective and less harmful than leaving it in place • Monitor recovery
Passive Uses	***Primary Restoration Strategy*** Any restoration strategy which aids recovery of injured resources, or prevents further injuries, will assist recovery of passive-use values. No strategy has been identified that benefits only passive uses, without also addressing injured resources.
Subsistence	***Primary Restoration Strategy*** • Promote recovery of subsistence as soon as possible • Remove or reduce residual oil if it is cost effective and less harmful than leaving it in place • Protect subsistence resources from further degradation • Monitor recovery

Objectives and Strategies by Resource and Service

Archaeological Resources

Recovery Status: Injury to archaeological resources stems from increased looting and vandalism of sites and artifacts, and erosion within and around the sites resulting from clean-up activities. In addition, archaeological artifacts may have been oiled. Injuries attributed to looting and vandalism still occur. These injuries diminish the availability or quality of scientific data and opportunities to learn about the cultural heritage of people in the spill area.

Recovery Objective: Archaeological resources will be considered recovered when spill-related injury ends, and looting and vandalism are at or below pre-spill levels. Restoration cannot regenerate what has been destroyed, but it can prevent further degradation of sites as well as the scientific information that would otherwise be lost.

RECOVERY MONITORING STRATEGY: Background: The current evidence suggests that a majority of the archaeological site vandalism that can be either directly or indirectly linked to the *Exxon Valdez* oil spill event occurred in 1989 before adequate constraints were put into place over the activities of oil spill clean-up personnel. Most of this vandalism took the form of prospecting for sites with high artifact yields. Numerous small holes, from 0.5 to 2.0 meters in size, were dug by vandals in 17 known sites (Projections based on existing data suggest that about 100 additional sites were similarly vandalized.).

Evidence of vandalism dropped dramatically after 1989, probably reflecting the more effective archaeological constraint system that had been put into place by the participating agencies, with the cooperation of Exxon Corp., by the late summer of 1989. This apparent drop in vandalism was unexpected and at first suggested that continued vandalism related to the *Exxon Valdez* spill event might not be a significant future concern. However, based on what we know about the behavior patterns of archaeological looters, the activity focus of vandals may have shifted (or will shift) from general prospecting to a more focused pattern of looting at a select number of high-yield archaeological sites that were identified by looters during the initial "prospecting" phase, or simply observed by more discrete potential looters engaged in clean-up operations in the post-1989 era. Artifact hunters are most likely to act on the opportunities presented by this knowledge in the next 15 years while their memories remain fresh; thereafter, the threat should gradually drop as the information loses "immediacy" and specificity.

A second oil-spill factor may greatly increase the likelihood that looter knowledge gained in the oil-cleanup period might be activated at any time at high-yield sites. The injury to commercial and subsistence species (e.g., harbor seals and herring) may create conditions of economic depression in several Gulf of Alaska communities that will increase the temptation to turn to commercial archaeological looting as an alternative source of income to make up for the income loss in other sectors. (Note: Loss of subsistence species forces users to use limited cash to purchase food and other products.) Studies of the economics of archaeological looting in Utah and elsewhere, such as St. Lawrence Island, have shown that commercial digging increases in communities that are experiencing economic downturns.

Another compelling reason to be concerned is that demand for Alaskan archaeological materials is at an all-time high by art dealers, jewelers, and knife makers. The prices of single slate ulus now approach $500 at certain galleries; rare pieces of ivory and bone may be sold for over $100,000.

Strategy: Archaeological monitoring of archaeological sites injured by the spill or spill-related activities will target a small number of sites which are determined to represent those that are most vulnerable to serious, commercial looting. There will be two categories of sites scheduled for continued monitoring. The first group, or index group, will consist of four known sites that will be monitored on a yearly basis for signs of vandalism. The selection of these sites will be based on their potential vulnerability to pot hunting and will be independent of jurisdiction. That is, no attempt will be made to distribute index sites equally by political jurisdiction or agency jurisdiction. One or two of these sites will also be selected for continued hydrocarbon monitoring so the behavior and effect of oiling can be observed over the long term in archaeological deposits. A second group of four sites will be selected for monitoring, but on a biannual basis. This second group of sites may vary over time in order to maintain flexible response to new information such as fresh reports of vandalism or new findings on patterns of looting. The second group of sites provides a cross-check to monitoring data collected at the index sites. By focusing annual monitoring on four index sites and using a two-year monitoring schedule on the additional four "cross-check" sites, expenditures would be kept to a minimum, but at a level that would still provide adequate tracking of vandalism trends over the years.

Because baseline data have already been collected on the sites that would be monitored, local people and communities will be included in the monitoring effort whenever possible. Agency archaeologists will serve as managers of the monitoring effort and conduct any specialized or difficult monitoring actions. This local involvement will also serve as a social mechanism for discouraging certain individuals from engaging in looting by encouraging the growth of cultural pride and heritage knowledge in the communities. Guidance for obtaining local participation will be sought in the results of the initial phase of the already funded "Community Archaeological Site Protection Plans Project." The first phase of this project, which will outline an effective approach for the involvement of local communities in archaeological protection, will be completed by the Office of History and Archaeology, State of Alaska, by September/October 1994. In order to avoid duplication of effort, every effort will be made to coordinate and integrate the archaeological monitoring program with the community archaeological protection activities.

Monitoring Schedule: Monitoring of index sites will occur on a yearly basis. This schedule is necessary to interdict vandalism before the damage has become severe and to insure that all signs of vandalism would be visible (e.g., unvegetated ground). The second group of sites will be monitored on a biannual basis which should be sufficient to identify at least the majority of vandalism indicators before they are hidden by vegetation. If monitoring indicates a strong recovery trend by the year 2000, the monitoring interval for index sites can shift to every two years and the interval for cross-check sites to every four years.

Estimated Recovery Time: Recovery will have been achieved when all vandalism that was stimulated by the *Exxon Valdez* oil spill has ceased and any required data recovery actions (e.g., professional excavation of looted site areas) or other mitigative actions (e.g., stabilization of vandalized site areas) designed to address documented injury have been completed. The best professional judgement estimates the achievement of recovery by the year 2020. This period of time should see the present generation of archaeological looters disappear, hopefully discouraged by local community education programs, site protection programs, and the social pressures created by a citizenry having a sense of "ownership" and pride in their archaeological heritage. In addition, a thirty-year span should result in the dissipation of any remaining oil contamination in archaeological deposits.

RESEARCH STRATEGIES: Archaeological sites are a promising source of long-term ecological data. The archaeological record, though often coarse-grained in terms of precise dates, may offer answers to some of the questions posed by contemporary ecosystem scientists who are trying to discriminate between changes that have links to the oil spill and those that represent fluctuations in natural systems over time.

Another source of long-term data may be found through ethnographic and historical research. Native Alaskans over the past millennia have accumulated a rich storehouse of information about the local environment, and though much of this knowledge has been lost of late, much still survives. The survival of coastal Native peoples has always depended on accurate, empirical observations about the world and its fickle environment. Historical archives and the memories of non-Native Alaskans also may offer valued information on the operation of the environment in the past.

Two hypotheses have been identified for using archaeological resources to study cultural dynamics and ecological history. The hypothesis for cultural dynamics is that ecosystem shifts have caused major cultural shifts in the spill area. The hypothesis for ecological history is that archaeological, ethnographic, and historic data can produce an informed comparative baseline for EVOS ecosystem studies. Existing archaeological collections may contain faunal/floral samples which will provide critical insights into specific ecosystem problems. Once assessed, the existing data should be supplemented by specific site excavation designed to fill in data gaps.

GENERAL RESTORATION STRATEGIES: In the FY 94 work plan, the Trustee Council approved Project 94007. Through this project, Community Archeological Site Protection

Plans are being prepared by the Office of History and Archaeology, State of Alaska. These plans will address such topics as stabilizing eroding sites, removing and restoring artifacts, the reduction of looting and vandalism, the removal of artifacts from sites and storage in an appropriate facility, and affording the opportunity to view or learn about the cultural heritage of people in the spill area. Implementation of these protection plans should be a top priority for general restoration projects for archaeological resources. Although the plans will not be in final, peer-reviewed form until May 1995, a draft of the plans will be ready by October 1994 and should serve as the basis of preparatory projects.

Bald Eagles

Recovery Status: Two hundred to 300 bald eagles may have been killed in the spill. However, population estimates made in 1989, 1990, and 1991 indicate that there may have been an increase in the PWS bald eagle population since the previous survey conducted in 1984. Productivity decreased in 1989, but appeared to have recovered by 1990.

Recovery Objective: Because population and productivity appear to have returned to pre-spill levels, bald eagles may have already recovered from the effects of the spill.

RECOVERY MONITORING STRATEGY: Aerial surveys of Prince William Sound using fixed wing aircraft were used before and after the spill to estimate bald eagle population size. Based on modelling, the Prince William Sound eagle population was expected to increase to its pre-spill level by 1994. Aerial surveys will be conducted in 1995 to verify this prediction. Productivity of Prince William sound bald eagles will be measured using helicopter surveys in 1995 to verify that it is normal given the dramatic declines of its major prey species, pink salmon. If population and productivity of Prince William Sound bald eagles is normal in 1995, monitoring will be conducted at five-year intervals. If the 1995 surveys indicate declines in population or productivity, more frequent surveys will be conducted. There is not enough pre-spill data on eagle populations in other parts of the spill area to warrant surveys outside Prince William Sound.

Monitoring Schedule: A PWS population and productivity survey should be conducted every five years starting in 1995.

Estimated Recovery Time: 5 years

RESEARCH AND GENERAL RESTORATION STRATEGIES: Bald eagles are recovering and may have recovered from the spill. No research or general restoration strategies are expected for the 1995 Work Plan.

Black Oystercatcher

Recovery Status: Black Oystercatchers are recovering, although oystercatchers may still be exposed to hydrocarbons when feeding in intertidal areas.

Recovery Objective: Black oystercatchers will have recovered when Prince William Sound populations attain pre-spill levels and when reproductive success of nests and growth rates of chicks raised in oiled areas are comparable to those in unoiled areas.

RECOVERY MONITORING STRATEGY: Population abundance and distribution in Prince William Sound will be monitored during boat surveys for marine birds and mammals. Growth rates of chicks will be monitored every two years.

Monitoring Schedule: Boat surveys of Prince William Sound bird populations should be conducted in the summer every three years starting in 1996. Chick growth rates will be monitored every two years for a six-year period starting in 1995.

Estimated Recovery Time: Unknown

RESEARCH AND GENERAL RESTORATION STRATEGIES: No research or general restoration strategies have yet been identified for the 1995 Work Plan.

Clams

Recovery Status: Littleneck clams and butter clams on sheltered beaches were killed by oiling and clean-up activities. In addition, growth appeared to be reduced by oil, but determination of sublethal or chronic effects is awaiting final analyses.

Recovery Objective: Clams will have recovered when populations and productivity have returned to levels that would have prevailed in the absence of the oil spill (pre-spill data or non-oiled control sites).

RECOVERY MONITORING STRATEGY: Paired oiled and non-oiled (control) clam beds will be sampled. Measures should be density and size-frequency distribution. Random sampling design within sites. Number and location of study sites to be determined from agency data and local subsistence usage. Consider sites throughout spill impact area.

Monitoring Schedule: Conduct one comprehensive study and then evaluate need for further monitoring.

Estimated Recovery Time: Unknown

RESEARCH AND GENERAL RESTORATION STRATEGIES: No research or general restoration strategies have yet been identified for the 1995 Work Plan.

Commercial Fishing

Recovery Status: Commercial fishing was injured through injury to commercial fish species and also through fishing closures. Continuing injuries to commercial fishing may cause hardships for fishermen and related businesses. Each year that commercial fishing remains below pre-spill levels compounds the injury to the fishermen and, in many instances, the communities in which they live and work.

The Trustee Council recognizes the impact to communities and people of the Prince William Sound region resulting from the sharp decline in pink salmon and herring fisheries in past years. In the 1994 work program, the Trustee Council has committed to the expenditure of five million dollars to help address these issues through the development of an ecosystem-based study for PWS. Some of the pink salmon and herring problems may be unrelated to the spill. However, the Council will continue to address these important problems as they relate to the oil spill.

Recovery Objective: Commercial fishing will have recovered when the population levels and distribution of injured or replacement fish used by the commercial fishing industry match conditions that would have existed had the spill not occurred. Because of the difficulty of separating spill related effects from other changes in fish runs, the Trustee Council may use pre-spill conditions as a substitute measure for conditions that would have existed had the spill not occurred.

RECOVERY MONITORING STRATEGY: The strategy we have taken thus far is to assess the fishery resources used by the commercial fishing industry to determine whether they were damaged and, if so, whether they are recovering. For example, we are trying to assess the health of the Prince William Sound pink salmon and Pacific herring populations as well as the status of Kenai River sockeye salmon by improving abundance estimation techniques. This is not an easy task since we have to deal with stock identification problems (wild and hatchery stocks in the case of Prince William Sound pink salmon) in order to sort out abundance/survival trends in stocks which seem to have been damaged by the oil spill. In some cases this has entailed marking studies (e.g., Prince William Sound pink salmon and Kenai River sockeye salmon smolts), genetic studies (e.g., Kenai adult sockeye salmon), hydroacoustic surveys (e.g., Kenai sockeye salmon adults and juveniles), and SCUBA surveys (e.g., Prince William Sound herring). Other stocks were studied for a short time (e.g., clams, shrimp, rockfish). So, it may be wise to collect some additional information in the future. In any case, an ecosystem approach, such as is proposed in the SEA study, might lead to a better understanding of injuries as well as better estimates of recovery time.

Monitoring Schedule: At this time, it is difficult to recommend doing monitoring on anything other than an annual basis for pink salmon, herring, or sockeye salmon. For example, pink salmon populations on odd and even years are essentially genetically isolated while herring and sockeye salmon are composed of multi-aged cohorts of siblings. So, it would appear that critical information could be lost if monitoring was done, for example, only on alternate years. For clams, shrimp, rockfish, etc., it might be advisable to monitor these on some longer interval (e.g., every two or three years).

Estimated Recovery Time: It is difficult to estimate this for the fishery resources being studied at this time. For example, the next two years are critical for judging recovery of Kenai River sockeye salmon. If good runs occur this year and next year, the population has probably recovered. This year is critical for Prince William Sound herring, which apparently were not very abundant (and were diseased) last year. Some Prince William Sound pink salmon populations may have been reproductively damaged, and it is difficult to determine when they might recover (either with or without restoration efforts).

RESEARCH AND GENERAL RESTORATION STRATEGIES: Research and general restoration strategies intended to restore commercial fishing are discussed under the individual commercial fishing resources including pink salmon, sockeye salmon, herring, and rockfish. No research or general restoration strategies have yet been identified for the 1995 Work Plan that restore commercial fishing directly without restoring a commercial fish resource.

Common Murres

Recovery Status: Productivity of common murres shows signs of recovery at some injured colonies (Barren Islands, Paule Bay) but post-spill population counts are still lower than pre-spill estimates and show no sign of recovery.

Recovery Objective: Common murres will have recovered when population trends are increasing significantly at index colonies in the spill area and when reproductive timing and success are within normal bounds. (Normal bounds will be determined by comparing productivity data with information from other murre colonies in the Gulf of Alaska and elsewhere.)

RECOVERY MONITORING STRATEGY: Populations at the Chiswell Islands, Barren Islands, Triplets, Ugaiushak Island and Paule Bay, the designated index colonies within the spill area, will be surveyed once every three years to determine if populations have recovered. Productivity will be monitored annually for four years at the Barren Islands to insure it is within normal bounds.

Monitoring Schedule: A complete population survey of injured colonies will be conducted every three years starting in 1996. Reproductive studies will be continued annually for four years, starting in 1995, then terminated if productivity is normal.

Estimated Recovery Time: 15-70 years

RESEARCH: *Multiple-resource Research.* The high-priority research issues for common murre are ecosystem processes: climate/oceanographic features, prey limitation and predation. Since the 1970s, murres along with other pelagic-feeding resources such as marbled murrelets, harbor seals, and other marine mammals and seabirds have been declining in the northern Gulf of Alaska and Prince William Sound. See Chapter 3: Pelagic Ecosystem, and the discussion of individual factors — climatic/oceanographic features, prey limitation, and predation.

Research Specific to Murres. Avian predation is considered a high-priority issue for common murres. See Chapter 3: "Has predation increased?" Also a concern, but a lesser priority, is the question of whether behavioral changes in common murres have decreased breeding productivity at some colonies. See Chapter 3: "Behavior Change."

GENERAL RESTORATION: No general restoration strategies have been identified for the 1995 Work Plan. Restoration techniques to initiate recovery are unlikely until scientists have determined why common murres are not recovering.

Cutthroat Trout

Recovery Status: Cutthroat trout have grown more slowly in oiled areas than in unoiled areas. Insufficient data are available to determine whether they are recovering.

Recovery Objective: Cutthroat trout will have recovered when growth rates within oiled areas are comparable to those for unoiled areas.

RECOVERY MONITORING STRATEGY: Monitor growth rates in injured populations to determine when the recovery objective has been met. Analysis of scale or otolith growth patterns may be a cost-effective approach to comparing current and past growth histories.

Monitoring Schedule: Every three years, continued at least one interval after the recovery objective has been met.

Estimated Recovery Time: Unknown

RESEARCH: No specific research issues were developed for the injured fish resources whose recovery status is unknown. Rather, the focus for cutthroat trout should be on determining if natural recovery is occurring.

GENERAL RESTORATION: Stock-separation information to help management protection is a useful but not high-priority general restoration technique for cutthroat trout.

Conservative limits on sport-fish harvest of cutthroat trout have been adopted in Prince William Sound. These management measures are likely to continue until the fish recover from the spill. While recovery status is unknown, the impact of the protective measures could be minimized by management information that allows the Alaska Department of Fish and Game to vary harvest regulations by time or location to minimize incidental catch of the injured runs of cutthroat. This task typically involves some type of marking so that fisheries managers can determine the portion of the catch (at different locations and times) that originates from the different runs. This information is beyond that historically gathered by the department and would allow it to manage fishing to protect the injured runs — to minimize interference with natural recovery.

Designated Wilderness Areas

Recovery Status: The oil spill delivered oil in varying quantities to the waters adjoining the seven areas within the spill area designated as wilderness (including wilderness study areas). Oil was also deposited above the mean high tide line in these areas. During the intense clean-up seasons of 1989 to 1990, hundreds of workers and thousands of pieces of equipment were at work in the spill area. This activity was an unprecedented imposition of people, noise, and activity on the area's undeveloped and normally sparsely occupied landscape.

Recovery Objective: Designated Wilderness Areas will have recovered when oil is no longer encountered in these areas and the public perceives them to be recovered from the spill.

RECOVERY MONITORING, RESEARCH, AND GENERAL RESTORATION STRATEGIES: Any restoration objective which aids recovery of injured resources, or prevents further injuries, will assist recovery of designated wilderness areas. No strategy has been identified that benefits designated wilderness areas without also addressing injured resources. For that reason, no monitoring specific to designated wilderness areas is proposed.

Monitoring Schedule: No monitoring specific to designated wilderness areas is proposed. However, monitoring the fate of the oil will continue to identify the existence and concentrations of *Exxon Valdez* oil in designated wilderness areas (For information about monitoring the presence of oil, see "Fate and Persistence of Oil" in this appendix.).

Dolly Varden

Recovery Status: Dolly Varden have grown more slowly in oiled areas than in unoiled areas. Insufficient data are available to determine whether they are recovering.

Recovery Objective: Dolly Varden will have recovered when growth rates within oiled areas are comparable to those for unoiled areas.

RECOVERY MONITORING STRATEGY: Monitor growth rates in injured populations to determine when the recovery objective has been met. Analysis of otolith growth patterns may be a cost-effective approach to comparing current and past growth histories.

Monitoring Schedule: Every three years, continued at least one interval after the recovery objective has been met.

Estimated Recovery Time: Unknown

RESEARCH: No specific research issues were developed for the injured fish resources whose recovery status is unknown. Rather, the focus for Dolly Varden should be on determining if natural recovery is occurring.

GENERAL RESTORATION: Stock-separation information to help management protection is a useful but not high-priority general restoration technique for Dolly Varden.

Conservative limits on sport-fish harvest of Dolly Varden trout have been adopted in Prince William Sound. These management measures are likely to continue until the fish recover from the spill. While recovery status is unknown, the impact of the protective measures could be minimized by management information that allows the Alaska Department of Fish and Game to vary harvest regulations by time or location to minimize incidental catch of the injured runs of Dolly Varden. This task typically involves some type of marking so that fisheries managers can determine the portion of the catch (at different locations and times) that originates from the different runs. This information is beyond that historically gathered by the department and would allow it to manage fishing to protect the injured runs — to minimize interference with natural recovery.

Harbor Seals

Recovery Status: Harbor seal numbers were declining in Prince William Sound (PWS) before the spill. Following the spill, seals in the oiled area had declined 43%, compared to 11% in the unoiled area. Counts made during the molt at trend count sites in Prince William Sound during 1990-1993 indicate that numbers may have stabilized. However, counts during pupping have continued to decline. It is not known which counts are the best indicator of population status. If the conditions that were causing the population to decline before the spill have improved, normal growth may replace the animals that were lost. However, if conditions continue to be unfavorable, the affected population may continue to decline. Harbor seals are a key subsistence resource in PWS and subsistence hunting is both affected by and may be affecting harbor seal status.

Recovery Objective: Recovery will have occurred when harbor seal populations trends are stable or increasing.

RECOVERY MONITORING STRATEGY: Aerial surveys of 25 trend count sites in PWS will be conducted during pupping and molting for comparison with previous years' data.

Monitoring Schedule: Aerial surveys will be conducted annually for the next two years. Periodicity of monitoring will be reevaluated after 1996, in light of population trend and indications of recovery. To date, it is not clear whether the population has stabilized in PWS or is continuing to decline. This species has declined more than 50% throughout the northern Gulf of Alaska and PWS in the last decade. It is currently being considered for listing as depleted under the Marine Mammal Protection Act. Data on current population status are necessary to avoid unnecessary regulation of fisheries in PWS and to provide information to subsistence hunters that will allow them to make informed decisions about levels of harvest. This monitoring program is very inexpensive to conduct.

Estimated Recovery Time: Unknown. If the ongoing decline is caused by food limitation or other unidentified factors that continue to be limiting, the population (including that segment that was damaged by the oil spill) may not recover.

RESEARCH: *Multiple-resource Research.* Harbor seal populations in PWS and the northern Gulf of Alaska have been declining for over a decade. The EVOS caused additional mortality in the spill area. In the four years since the EVOS, seal numbers have not shown any indication of recovery. In contrast, seals in southeast Alaska and Canada appear healthy and increasing. The reasons for the decline in the northern Gulf and PWS are unknown, but limited (or changing) availability of prey, particularly forage fishes, has been suggested as a cause for the decline. It is not possible, however, to eliminate other causes such as disease, predation by killer whales, harvest, or take by fisheries, or several of these factors in combination.

Of these factors, hypotheses relating to prey limitation, predations, and resource exploitation are high-priority research areas for explaining the harbor seal decline. Specific research hypotheses include: (1) The decline in harbor seals in PWS (and the Gulf of Alaska) has occurred primarily because of changes in the availability of prey, particularly forage fishes; and (2) Predation by killer whales has caused or exacerbated the harbor seal decline, and/or prevented recovery. General issues considered important, but not as likely to explain the decline, include research on the definition of habitat effects and oceanographic processes on recruitment, growth, condition, and survival; and impacts of disease on harbor seals in Prince William Sound. See Chapter 3: Pelagic Ecosystem, and discussion of individual factors — food limitation, and predation.

Research Specific to Harbor Seals. Resource exploitation is a high-priority issue for harbor seals. Harbor seal numbers are greatly reduced because of the area-wide decline, which was exacerbated by additional spill-related mortality. At this reduced level, the population may be impacted by any additional mortality, such as that caused by subsistence harvest or take associated with fisheries. See Chapter 2 discussion of "Resource Exploitation."

GENERAL RESTORATION: It would help restoration to determine if Prince William Sound animals are genetically distinct or different populations from those in the Gulf of Alaska or Southeast Alaska. This information about whether the populations are distinct or intermingle would be helpful in allowing subsistence hunters to assess the effects of their harvest. It would also be useful in understanding how the region-wide decline in harbor seals affects the population in the spill area.

Harlequin Ducks

Recovery Status: There are indications of reduced densities of birds in the breeding season; a declining trend in the summer, post-breeding population; and very poor production of young in western Prince William Sound.

Recovery Objective: Harlequin ducks will have recovered when breeding and post-breeding season densities and production of young return to estimated pre-spill levels, or when there are no differences in these parameters between oiled and unoiled areas.

RECOVERY MONITORING STRATEGY: A survey that will provide an estimate of breeding-age adults to assess reproductive capability in the population and establish numerical recovery objectives will be conducted in 1995. After 1995, a May-June boat survey every three years should provide indications of change in the potential breeding population. Annual production of young is currently very low in the spill area and is normally highly variable in harlequin ducks. Annual monitoring is recommended for the next five years to confidently detect any signs of improvement amid expected fluctuations. Monitoring would be accomplished with a shoreline boat survey during late August and September, providing data on numbers of young, brood distribution, and abundance of post-breeding harlequins.

Monitoring Schedule: Conduct May-June breeding population survey every three years beginning in 1995. Conduct a production/post-breeding survey annually 1995-1999.

Estimated Recovery Time: Unknown. Intrinsic annual growth rates for harlequin duck populations may be 10% or less. Slow maturation and annually varying breeding propensity further inhibit population increase.

RESEARCH: The breeding population of harlequin ducks in western Prince William Sound has suffered consistent reproductive failure. The reasons for this chronic recruitment failure since the spill is unknown, but the leading hypothesis is that ingestion of oil-contaminated prey from foraging in oiled mussel beds has affected the reproductive success of the resident birds. This is a high-priority issue for harlequin ducks. See discussion of individual factors in Chapter 3: "Direct Toxicity" and "Recruitment Processes."

GENERAL RESTORATION: In 1994, the Trustee Council funded the cleaning of contaminated mussel beds, primarily in Prince William Sound. If these mussel beds are the cause of the continued oil contamination and reproductive failure, the continued cleaning of any remaining contaminated mussel beds will be a continued high priority. The continuation of the 1994 project is dependent on the results of this summer's project.

Intertidal Organisms

Recovery Status: The lower intertidal zone and, to some extent, the middle intertidal zone are recovering. However, injuries persist in the upper intertidal zone, especially on rocky sheltered shores. Recovery of this zone appears to depend, in part, on the return of adult Fucus in large numbers.

Recovery Objective: Each intertidal elevation (lower, middle, or upper) will have recovered when community composition, population abundance of component species, age class distribution and ecosystem functions and services in each injured intertidal habitat have returned to levels that would have prevailed in the absence of the oil spill.

RECOVERY MONITORING STRATEGY: Monitor selected matched oiled and non-oiled (control) sites throughout the spill area, incorporating a variety of habitats in each region. To validate the inference of recovery for the matched-pair design, matched non-oiled sites should be monitored also.

Monitoring Schedule: Monitor Prince William Sound paired sites in 1995 and 1997. Monitor Cook Inlet/Kenai Peninsula and Kodiak/Alaska Peninsula in 1996 and 1998. Further monitoring cycles should be dependent upon results of initial four years.

Approximately one-half of the site pairs would be within Prince William Sound and the other one-half in the other two regions combined. Because of the matched-pair design and the need to make comparisons within regions (which were shown to differ), a two-year monitoring cycle is necessary. This monitoring strategy provides continuity and level effort between years.

In addition, monitoring of Herring Bay intertidal sites will occur annually.

Estimated Recovery Time: Unknown

RESEARCH: The high-priority research issues for the nearshore ecosystem including intertidal and subtidal organisms are ecosystem process questions. See Chapter 3: "Nearshore Ecosystem" and "Community Structure." See also discussion of other factors — predation, competition, and physical/oceanographic factors.

GENERAL RESTORATION: No general restoration strategies have yet been identified for the 1995 Work Plan.

Killer Whales

Recovery Status: Thirteen whales disappeared from one pod in Prince William Sound between 1988 and 1990. The injured pod is growing again.

Recovery Objective: Killer whales will have recovered when the injured pod grows to at least 36 individuals (1988 level).

RECOVERY MONITORING STRATEGY: Photographs of individual killer whales occurring in AB pod will be collected to document natural recovery. Because AB pod whales frequently associate with other Prince William Sound resident killer whale pods (approximately 80% of all encounters), it is necessary to photograph all killer whale pods/individuals encountered during field research in Prince William Sound.

Monitoring Schedule: Field research every two years will allow us to keep track of new births by year and record regrowth of the pod. Natality and mortality rates will be conservative biennial estimates, and missing whales will not be confirmed as dead until two years after they are first missing.

Estimated Recovery Time: Recovery of AB pod to pre-spill levels (36 whales) could take ten to fifteen years given the current age and sex structure of the population.

RESEARCH AND GENERAL RESTORATION STRATEGIES: No research or general restoration strategies have been identified for the 1995 Work Plan.

Marbled Murrelet

Recovery Status: Marbled murrelet populations in Prince William Sound were in decline before the spill. The causes of the pre-spill decline are unknown.

Recovery Objective: Marbled murrelets will have recovered when population trends are increasing.

RECOVERY MONITORING STRATEGY: Estimate the Prince William Sound marbled murrelet population in July using standard U.S. Fish and Wildlife Service boat surveys.

Monitoring Schedule: Boat surveys of Prince William Sound bird populations should be conducted in the summer every three years starting in 1996.

Estimated Recovery Time: Unknown

RESEARCH: *Multiple-resource Research.* Research concerning ecosystem processes are high-priority research issues for marbled murrelets: climatic/oceanographic features, prey limitation and predation. Since the 1970s, marbled murrelets along with other pelagic-feeding resources such as murres, harbor seals, and other marine mammals and seabirds have been declining in the northern Gulf of Alaska and Prince William Sound. See Chapter 3: Pelagic Ecosystem, and the discussion of individual factors — climatic/oceanographic features, prey limitation, and predation.

Research Specific to Marbled Murrelets. Avian and mammalian predation is considered a high-priority issue for marbled murrelet. See Chapter 3: "Has predation increased?" Also a concern, but a lesser priority, is further research on the effects of resource exploitation (incidental gillnet catch) and upland development. However, protection of habitat remains an important strategy for protecting recovery. See Chapter 3: "Predation" and "Resource Exploitation."

GENERAL RESTORATION: No general restoration strategies have been identified for the 1995 Work Plan. Restoration techniques to initiate recovery are unlikely until scientists have determine why marbled murrelets are not recovering.

Pacific Herring

Recovery Status: Pacific herring studies have demonstrated egg mortality and larval deformities. Populations may have declined, but there is uncertainty as to the full extent and mechanism of injury. However, the stocks and dependent fisheries in Prince William Sound are not healthy, as indicated by the low spawning biomass in 1993 and 1994 and the resultant elimination of the fisheries in those years.

Recovery Objective: Pacific herring will have recovered when populations are healthy and productive and exist at pre-spill abundances.

RECOVERY MONITORING STRATEGY: Monitor fish health and spawning biomass. Annual monitoring for fish health status will begin in 1994. Estimation of spawning biomass will require support of annual spawn deposition survey to supplement normal ADF&G data collection.

Monitoring Schedule: Annual monitoring until recovery objectives have been met, that is when a healthy, strong year-class has recruited into the spawning population. Continued annual monitoring for four additional years (one recruitment cycle) beyond meeting the recovery objectives to ensure recovery has been achieved.

Estimated Recovery Time: Unknown; no sooner than 1996 (1992 year-class), which will require annual monitoring until at least 2000.

RESEARCH: *Multiple-resource Research.* Research on ecosystem processes including climatic/oceanographic features, prey limitation, and predation, is a high priority for understanding why herring and pink salmon are not recovering in Prince William Sound. A basic hypothesis for an ecosystem approach to determining how processes in the pelagic ecosystem may control fluctuations in these fisheries resources has been identified. This hypothesis is that mortality and growth of pink salmon and herring in Prince William Sound are controlled by the standing biomass of zooplankton, as influenced by atmospheric and oceanic processes. The average residence time of the Sound's waters and the strength of advective transport of deeper waters from the Gulf of Alaska into the Sound, control the standing biomass of zooplankton. When zooplankton are abundant, predation pressure on juvenile salmon and herring is relatively low, and survival of the juveniles is higher. If zooplankton abundance is low, predatory fish and birds switch from a zooplankton diet to juvenile salmon and herring, thus reducing survival of the juveniles.

Other ecosystem processes that are high priority for herring research include the advective transport of herring larvae from rearing areas in the Sound, and the quality of winter conditions on the survival and reproductive success of the herring population. See Chapter 3: Pelagic Ecosystem, and discussion of individual factors — physical/oceanographic features, prey limitations, and predation.

Research Specific to Herring. The continued investigation of the effects of previous exposure to oil is a high-priority research area for herring. This exposure may have caused lethal and sublethal effects, and genetic damage to herring which may be inherited to succeeding generations. In addition, the effects of causes of viral hemorrhagic septicemia (VHS) is also a high-priority research area. See Chapter 3: "Direct Toxicity," "Heritable Genetic Damage," and "Is it Disease?"

GENERAL RESTORATION: Stock separation information to help management protection is a high-priority general restoration strategy for herring. The failure of the herring run in Prince William Sound in 1993 and 1994 prompted the Alaska Department of Fish and Game to close the fishery. Until the Sound-wide herring run is strong enough to support a commercial fishery, this closure will likely continue. During recovery, the impact of fishery management could be minimized by management information that allows the Alaska Department of Fish and Game to vary harvest regulations by time or location to minimize incidental catch of the injured runs of herring. This task typically involves stock separation so that fisheries managers can determine the portion of the catch (at different locations and times) that originates from the different runs. Marking programs and genetic stock identification are examples of management tools for stock separation. This information is beyond that historically gathered by the department and would allow it to manage fishing to protect the injured runs — to minimize interference with natural recovery. It allows this protection in a way that may allow earlier opening of the herring fishery in some parts of Prince William Sound. Unfortunately, stock separation techniques for herring are less well established than they are for salmon. There is some question about the technical feasibility of these techniques for herring.

Passive Use

Recovery Status: Passive use of resources includes the appreciation of the aesthetic and intrinsic values of undisturbed areas, the value derived from simply knowing that a resource exists, and other nonuse values. Injuries to passive uses are tied to public perceptions of injured resources.

Recovery Objective: Passive uses will have recovered when people perceive that aesthetic and intrinsic values associated with the spill area are no longer diminished by the oil spill.

RESEARCH, MONITORING, AND GENERAL RESTORATION STRATEGY: Any restoration activity that aids recovery of injured resources, or prevents further injuries, will assist recovery of passive-use values. No strategies have been identified which benefit only passive uses without also addressing injured resources. Since recovery of passive uses requires that people know when recovery has occurred, the availability to the public of the latest scientific information will continue to play an important role in the restoration of passive uses. At some point, the Trustee Council may wish to survey perceptions about recovery, but no specific passive use monitoring is proposed at this time.

Monitoring Schedule: At this time, no monitoring specific to passive-use values is proposed.

Estimated Recovery Time: Unknown

Persistence of Oil (Intertidal Sediments, Mussels)

Oil itself is not an injured resource or service. It is the cause of the injuries. Monitoring the fate and persistence of oil in the environment including location, concentration, and toxicity provides foundation monitoring for remaining oil contamination in the ecosystem. It also provides specific recovery monitoring for continued contamination in sediments and mussels.

Recovery Status:

- *Prince William Sound.* Limited shoreline surveys and limited clean-up work occurred in 1991, 1992, and 1993. The surveys indicated that subsurface oil remained at many sites that were heavily oiled in 1989.

  In 1993, shoreline assessment surveys were conducted at over 75 sites in Prince William Sound. They found that oil residue was present at most sites and sheening occurred at some. They also found that surface oiling has become very stable.

There was no measurable reduction in surface asphalt and surface oil residue from 1992 to 1993. Subsurface oiling, on the other hand, has decreased substantially since 1991. Overall, the amount of subsurface oil found at the study sites in 1993 is about 45% of the amount found in the same areas in 1991.

- *Kodiak.* No sites have been surveyed on Kodiak Island since 1990.

- *Alaska Peninsula.* No general assessment work has been done since 1990. Five study sites were established in 1992 to examine the persistence and degradation of oil along national park coast lines. Those sites will be revisited in 1994. The 1992 observations indicate a continuing presence of oil at those sites.

- *Cook Inlet and Outer Kenai Coast.* Only limited assessment work has been done since 1990. A study site was established in 1992 to examine the persistence and chemical degradation of oil along national park coast lines. That site will be revisited in 1994. The 1992 observation indicates a continuing presence of oil at that site.

Recovery Objective: With respect to residual oil contamination, recovery has been achieved when remaining oil concentrations are reduced to a level comparable to pre-spill levels.

RECOVERY MONITORING STRATEGY: To assess the persistence of oil, monitoring needs to record the location, concentration, and characterization of oil that remains from the *Exxon Valdez* oil spill. Monitoring the location means periodically determining the areal extent until it reaches "recovery" levels in most areas, and focusing more frequent monitoring on "hot spots" where significant concentrations remain.

Monitoring Schedule:

- *Kodiak and Alaska Peninsula.* Comprehensive surveys have not been conducted since 1990. A survey should be conducted in 1995 to determine the areal extent and location of significant concentrations of remaining oil. The monitoring should be designed to give a comprehensive look at the distribution of oil in order to satisfy scientific and public information needs. Needs for future monitoring, if any, on Kodiak and the Alaska Peninsula will be determined based on the results from 1995.

- *Prince William Sound.* Specific areas in Prince William Sound were monitored in 1993. Monitoring is not needed in 1995. It should be conducted in 1996 to determine the location of significant concentrations of remaining oil. Like that for Kodiak and the Alaska Peninsula, the monitoring should be designed to give a comprehensive look at the distribution of oil in order to satisfy scientific and public information needs. It should not focus on known "hot spots" monitored in 1993, but be a broader effort to give a comprehensive picture. Future monitoring of specific remaining areas of high oil concentration will be determined based on the results from 1996.

- *Cook Inlet and Outer Kenai Coast.* Monitoring needs for Cook Inlet and outer Kenai Coast need not drive the monitoring schedule; rather, they should be incorporated into the projects for Kodiak and Prince William Sound as logistics opportunities are available.

Estimated Recovery Time: Unknown

RESEARCH: No research strategies have been identified for the 1995 Work Plan.

GENERAL RESTORATION: The 1994 Work Plan includes a project to accelerate the degradation of surface oil on beaches of important value to subsistence and recreation where the visual recognition of oil is diminishing these services. No strategies have been identified for the 1995 Work Plan.

Persistence of Oil (Mussel Beds)

Recovery Status: Mussels themselves are an injured resource, both from the recreational and subsistence view plus possibly as the vehicle for transferring petroleum hydrocarbons to higher consumers. High concentrations of petroleum hydrocarbons remain evident in some mussel beds within Prince William Sound, and preliminary results indicate contaminated beds outside Prince William Sound also.

Recovery Objective: Recovery will be complete when sediment petroleum hydrocarbons concentrations have declined to pre-spill concentrations.

RECOVERY MONITORING STRATEGY: Beds identified as contaminated should be monitored no more than once every three years. In order to maintain a level effort of work, one-third of these beds could be monitored each year.

Monitoring Schedule: Perform one cycle of monitoring, then re-evaluate.

Estimated Recovery Time: Unknown

RESEARCH: No research strategies have been identified for the 1995 Work Plan.

GENERAL RESTORATION: In 1994, the Trustee Council funded the cleaning of contaminated mussel beds, primarily in Prince William Sound. If these mussel beds are the cause of the continued oil contamination to harlequin ducks and other intertidal feeders, and reproductive failure to harlequin ducks, the continued cleaning of any remaining contaminated mussel beds will be a continued high priority. The continuation of the 1994 project is dependent on the results of this summer's project.

Persistence of Oil (Subtidal Sediments)

Recovery Status: Subtidal organisms living in or on sediments and demersal fish that forage in subtidal sediment habitats may be exposed to the petroleum hydrocarbons that may be contaminating the sediments. In 1991, shallow subtidal PAH composition patterns consistent with that of weathered *Exxon Valdez* oil were found mainly at Northwest Bay in the depth range 3 - 20 m. Reduced concentrations of the oil were found at some shallow water stations in Bay of Isles, Herring Bay, and Snug Harbor. Data in 1992 and 1993 on the fish exposed showed evidence of continued contamination.

Recovery Objective: Subtidal sediments will have recovered when concentrations of petroleum hydrocarbons in shallow (0 - 20 m) sediments approximate the petrogenic background concentration that prevailed prior to the *Exxon Valdez* oil spill and petroleum exposure indices in biota from oiled sites are similar to indices in biota from non-oiled sites.

RECOVERY MONITORING STRATEGY: Concentrations of hydrocarbons in shallow (0 - 20 m) subtidal sediments, and indices of petroleum exposure in flatfish will be monitored.

Monitoring Schedule: Sediments and biota should be monitored in 1995, and future monitoring should be dependent on 1995 results.

Estimated Recovery Time: Concentrations of petroleum hydrocarbons in shallow subtidal sediments are expected to recover to pre-oil spill levels in four to six years. Recovery time for biota exposure are not known.

RESEARCH AND GENERAL RESTORATION STRATEGIES: No research or general restoration strategies have been identified for the 1995 Work Plan.

Pigeon Guillemot

Recovery Status: The pigeon guillemot population in Prince William Sound was in decline before the spill. The causes of the pre-spill decline are unknown.

Recovery Objective: Pigeon guillemots will have recovered when populations are stable or increasing.

RECOVERY MONITORING STRATEGY: Estimate the Prince William Sound pigeon guillemot population in winter and summer using standard U.S. Fish and Wildlife Service boat surveys.

Continue June counts of pigeon guillemots attending colonies on Naked, Peak, Storey, Smith and Little Smith islands. The Naked Island area supports greater than 25% of Prince William Sound guillemots, and pre-spill and post-spill counts of the Naked Island area population provide excellent data for determining population trend. These data will provide an independent source of information to confirm trends found in the boat surveys.

Monitoring Schedule: Boat surveys of Prince William Sound bird populations should be conducted in winter and summer every three years starting in 1996. June counts of guillemots in the Naked Island area should be conducted every three years.

Estimated Recovery Time: Unknown

RESEARCH: *Multiple-resource Research.* Research concerning ecosystem processes are high-priority research issues for pigeon guillemot: climatic/oceanographic features, prey limitation and predation. Since the 1970s, pigeon guillemot along with other pelagic-feeding resources such as marbled murrelets, harbor seals, and other marine mammals and seabirds have been declining in the northern Gulf of Alaska and Prince William Sound. See Chapter 3: Pelagic Ecosystem, and the discussion of individual factors — climatic/oceanographic features, prey limitation, and predation.

Research Specific to Pigeon Guillemots. Predation of eggs and nestlings is an alternative but lower priority hypothesis for the lack of pigeon guillemot recovery. Mammalian predation is considered an only moderately important research issue for pigeon guillemots.

In the initial years of the spill, oil was found on eggs. Investigating the lingering effects of this oiling is considered only a moderate priority research hypothesis in explaining the lack of recovery. In addition, resource exploitation (e.g., incidental gillnet catch) is unlikely to explain the continued area-wide decline, and may have a potentially significant impact on recovery. See Chapter 3: "Direct Toxicity," "Is it Predation?" and "Resource Exploitation."

GENERAL RESTORATION: No general restoration strategies have been identified for the 1995 Work Plan.

Pink Salmon

Recovery Status: Pink salmon studies have demonstrated egg mortality, fry deformities, and reduced growth in juveniles. Populations may have declined, but there is uncertainty as to the full extent and mechanism of injury. However, there is evidence of continued damage in some stocks from exposure to oil, and there has been a precipitous decline to both wild and hatchery stocks of pink salmon in Prince William Sound since 1991.

Recovery Objective: Pink salmon will have recovered when populations are healthy and productive and exist at pre-spill abundance (An indication of recovery is when egg mortalities in oiled areas match pre-spill level or levels in unoiled areas.).

RECOVERY MONITORING STRATEGY: (1) Annual monitoring of egg mortality in a standardized set of oiled and non-oiled streams. (2) Monitoring of escapements and return per spawner productivity. Alaska Department of Fish and Game routinely monitors escapements throughout PWS as part of its management program; an additional increment of stock separation in the commercial fishery is necessary to accurately determine hatchery/wild stock fishery contributions, in order to estimate returns per spawner. This additional increment may be provided by higher-resolution management activities required as general restoration activity to ensure adequate escapement of impacted populations of pink salmon.

Monitoring Schedule: Annual monitoring until recovery objectives have been met, and for the subsequent generation (two years) after recovery objectives have been met to ensure recovery has been achieved.

Estimated Recovery Time: Unknown; at least two generations, depending on the mechanism of damage to reproductive success.

RESEARCH: *Multiple-resource Research.* Research on ecosystem processes including climatic/oceanographic features, prey limitation, and predation, is a high priority for understanding why herring and pink salmon are not recovering in Prince William Sound. A basic hypothesis for an ecosystem approach to determining how processes in the pelagic ecosystem may control fluctuations in these fisheries resources has been identified. This hypothesis is that mortality and growth of pink salmon and herring in Prince William Sound are controlled by the standing biomass of zooplankton, as influenced by atmospheric and oceanic processes. The average residence time of the Sound's waters and the strength of advective transport of deeper waters from the Gulf of Alaska into the Sound control the standing biomass of zooplankton. When zooplankton are abundant, predation pressure on juvenile salmon and herring is relatively low, and survival of the juveniles is higher. If zooplankton abundance is low, predatory fish and birds switch from a zooplankton diet to juvenile salmon and herring, thus reducing survival of the juveniles.

Research on the impacts of large-scale enhancement of pink salmon in Prince William Sound on the recovery and productivity of wild populations of pink salmon is also a high priority. See Chapter 3: Pelagic Ecosystem, and discussion of individual factors — climatic/oceanographic features, prey limitations, predation, and impact of hatcheries.

Research Specific to Pink Salmon. The continued investigation of the effects of previous exposure to oil is a high-priority research area for pink salmon. This exposure may have caused lethal and sublethal effects, and genetic damage to pink salmon which may be inherited to succeeding generations. See Chapter 3: "Direct Toxicity" and "Heritable Genetic Damage."

GENERAL RESTORATION: Stock-separation information to help management protection is a high-priority general restoration technique for pink salmon.

The poor returns of the pink salmon runs in Prince William Sound in 1992 and 1993 have prompted the Alaska Department of Fish and Game to restrict the fishery. Fishermen harvest both injured and healthy pink salmon runs. There is a need for more information to allow the Alaska Department of Fish and Game to vary harvest regulations by time or location to minimize incidental catch of the injured runs of pink salmon. This task typically involves some type of marking so that fisheries managers can determine the portion of the catch (at different locations and times) that originates from the different runs. This information is beyond that historically gathered by the department and would allow it to manage fishing to protect the injured runs — to minimize interference with natural recovery.

Recreation and Tourism

Recovery Status: The spill disrupted use of the spill area for recreation and tourism. Resources important for wildlife viewing include killer whale, sea otter, harbor seal, bald eagle, and various seabirds. Residual oil exists on some beaches with high value for recreation. It may decrease the quality of recreational experiences and discourage recreational use of these beaches.

Closures on sport hunting and fishing also affected use of the spill area for recreation and tourism. Sport fishing resources include salmon, rockfish, Dolly Varden, and cutthroat trout. Harlequin duck are hunted in the spill area.

Recreation was also affected by changes in human use in response to the spill. For example, displacement of use from oiled areas to unoiled areas increased management problems and facility use in unoiled areas. Some facilities like the Green Island cabin and the Fleming Spit camp area were injured by clean-up workers.

Recovery Objective: Recreation and tourism will have recovered, in large part, when the fish and wildlife resources on which they depend have recovered, recreation use of oiled beaches is no longer impaired, and facilities and management capabilities can accommodate changes in human use.

RECOVERY MONITORING STRATEGY: Stay advised of the recovery status of the resources upon which recreation activities depend. Interaction with the recreation user groups will be maintained by requiring oil spill funded resource projects to monitor recreation use in the project area. Identify oiled beaches which have or have had high attraction for recreation use where evidence persists as surface or subsurface oil. The 1991 Forest Service Customer Survey will be redone periodically to establish recovery trends.

Monitoring Schedule: Resource monitoring activities that relate to recreational use of the oil spill area will be scheduled as the scientists determine, and the data will be used by the agencies to monitor resource use-based recreation. Beaches with persistent oil will be monitored annually in mid-summer. The Customer Survey will be repeated in 1995, and three and six years hence, in an attempt to establish recovery and trend information.

Estimated Recovery Time: Use statistics are currently higher than for pre-spill years, but expression that oiled areas are not the same as they were prespill is prevalent. Continue beach monitoring as long as residual oil persists. When perception of oiling will be insignificant among recreationists is unknown.

RESEARCH AND GENERAL RESTORATION STRATEGIES: No research and general restoration strategies have been identified for the 1995 Work Plan.

River Otters

Recovery Status: River otters have suffered sublethal effects from the spill and continuing exposure to hydrocarbons.

Recovery Objective: Indications of recovery are when habitat use, food habitats, and physiological indices have returned to pre-spill conditions.

RECOVERING MONITORING STRATEGY: Monitor latrine sites for use by otters and reestablish use of abandoned sites to indicate populations recovery. Monitor species composition in feces to document return to pre-spill composition.

Monitoring Schedule: Two field trips yearly early summer and late summer.

Estimated Recovery Time: River otters are long-lived species; best case scenario - 15 years.

RESEARCH AND GENERAL RESTORATION STRATEGIES: No research and general restoration strategies have been identified for the 1995 Work Plan.

Rockfish

Recovery Status: Dead adult rockfish were recovered following the oil spill. Other rockfish were exposed to hydrocarbons and showed sublethal effects. Furthermore, closures to salmon fisheries increased fishing pressures on rockfish which may be affecting their population. However, the extent and mechanism of injury to this species are unknown.

Recovery Objective: Without further study, recovery cannot be defined.

RECOVERY MONITORING STRATEGY: No monitoring strategy can be determined without definition of a recovery objective. Synthesis of NRDA studies and other data on PWS rockfish is needed, with recommendations for recovery objective and monitoring approach a requirement of the synthesis project.

Monitoring Schedule: None

Estimated Recovery Time: Unknown

RESEARCH AND GENERAL RESTORATION STRATEGIES: The only research or general restoration task that has been identified for rockfish is synthesis of the available information in order to determine if restoration is needed.

Sea Otters

Recovery Status: Sea otters do not appear to be recovering, but are expected to eventually recover to their pre-spill population. Exactly what population increases would constitute recovery is very uncertain, as there is no population data from 1986 to 1989, and the population may have been increasing in eastern Prince William Sound during that time. In addition, only large changes in the population can be reliably detected with current measuring techniques. However, there are recent indications that the patterns of juvenile and mid-aged mortalities are returning to pre-spill conditions.

Recovery Objective: Sea otters will be considered recovered when population abundance and distribution are comparable to pre-spill abundance and distribution, and when all ages appear healthy.

RECOVERY MONITORING STRATEGY: The recovery monitoring program will track abundance and mortality of sea otters in oiled areas.

Abundance. Aerial surveys of sea otter abundance in areas of Prince William Sound most heavily impacted by the oil spill (areas around northern Knight Island and Naked Island) and in non-oiled areas of western PWS will be conducted in 1995 and 1997 and thereafter only if the number of sea otters in oiled areas remains lower than anticipated. Data on sea otter abundance collected as part of the seabird boat surveys will continue to be collected in the process of monitoring seabirds (at no extra cost to either the seabird or sea otter projects), and will be used to augment the aerial survey data on sea otter abundance in oiled areas. However, the aerial surveys have been developed specifically to provide accurate counts of sea otters whereas the boat surveys have been shown to be biased in their estimates. Thus data collected in the boat surveys will be relied upon only as supplementary information.

Mortality. Sea otter carcasses will be collected in oiled areas of Prince William Sound (the Green Island area) in the spring of 1995 and 1996. Ages of the otters at the time of death can be determined from the skulls. Pre-spill data on carcasses from this area indicated the proportion of prime-age otters in the carcass sample is normally low. However, mortality of prime-age otters was high postspill, through 1991. Since then, mortality patterns appear to be returning to normal. Two more seasons of carcass collection will allow us to confirm that mortality patterns in the population are similar to prespill. An advantage of assessing mortality through collection of carcasses is that the work can be completed in a short time at a relatively low cost.

Monitoring Schedule:

1995	Aerial surveys, Carcass collection
1996	Carcass collection
1997	Aerial surveys
1998	Only if data collected in 1996 suggests recovery is not occurring
1999	Aerial surveys, if needed
2001	Aerial surveys, if needed

Monitoring Schedule Justification: Unusually low densities of sea otters have been observed in heavily oiled areas of PWS and no increases have been detected since the spill. Maximum annual growth rates in sea otter populations are 0.21. Based on an estimated annual increase of 0.10 and α and β = 0.20, a significant difference between two biannual surveys could be detected. If the annual change is 0.05, three surveys (1995, 1997, 1999) would be required to detect statistical significance.

Estimated Recovery Time: Unknown. No increase in population size has been observed since the spill.

RESEARCH: For sea otters, high priority is given to questions focused on the continued impacts of oiling, both by direct toxicity and altered community structure, and on prey limitation on recovery. Specific research hypotheses relative to these factors are: (1) direct exposure to hydrocarbons and ingestion of contaminated prey has impacted current or future survival and reproductive success of sea otters in Prince William Sound; and (2) the oil spill induced changes in population of benthic prey species that have limited re-occupation of sea otter habitat and the recovery of sea otters in oiled areas. See Chapter 3: Nearshore

Ecosystem, and discussion of individual factors — community structure, direct toxicity and prey limitations.

GENERAL RESTORATION STRATEGIES: No general restoration strategies have been identified for the 1995 Work Plan.

Sockeye Salmon

Recovery Status: Sockeye salmon in Red Lake, Akalura Lake, and lakes in the Kenai River system declined in population because of adult overescapement in 1989. The Red Lake system may be recovering because the plankton has recovered, and fry survival improved in 1993. However, Akalura Lake and Kenai River Lakes have not recovered: smolt production has continued to decline from these lakes. In the Kenai River Lakes, for example, smolt production has declined from 30 million in 1989 to 6 million in 1990, and to less than 1 million in 1992 and 1993.

Recovery Objective: Sockeye salmon in the impacted lakes will have recovered when populations are able to support overwinter survival rates and smolt outmigrations comparable to pre-spill levels.

RECOVERY MONITORING STRATEGY: In Red Lake and Akalura Lake, monitoring of smolt outmigrations. In Kenai River Lakes, monitoring of fall fry abundance and smolt abundance to estimate overwinter survival and smolt production.

Monitoring Schedule: Annually until recovery objectives have been met, and for two subsequent years after smolt productivity has returned to normal. Thus two more years of monitoring at Red Lake are required to confirm recovery, while at least seven years of monitoring will be necessary at Kenai and Akalura Lake to monitor productivity through returns of year-classes damaged by spill-induced overescapements.

Estimated Recovery Time: For Akulara Lake and Kenai River Lakes, recovery time is unknown, but is believed to be a minimum of seven years. Red Lake may be considered fully recovered in two years.

RESEARCH: High-priority research concerning sockeye salmon entirely concern ecosystem processes. See Chapter 3: Upland Ecosystem, and discussion of individual factors — community structure, prey limitation, predation, and competition.

GENERAL RESTORATION: Stock-separation information to help management protect injured sockeye salmon is a high-priority general restoration technique.

The diminished sockeye salmon smolt production in the Kenai and Kodiak area lakes is likely to prompt the Alaska Department of Fish and Game to restrict the fishery. Fishermen harvest both injured and healthy sockeye salmon runs. There is a need for more information to allow the Alaska Department of Fish and Game to vary harvest regulations by time or location to minimize incidental catch of the injured runs. This task typically involves some type of marking so that fisheries managers can determine the portion of the catch (at different locations and times) that originates from the different runs. This information is beyond that

historically gathered by the department and would allow it to manage fishing to protect the injured runs — to minimize interference with natural recovery.

Subsistence

Recovery Status: Subsistence users say that maintaining their subsistence culture depends on uninterrupted use of subsistence resources. The more time users spend away from subsistence activities, the less likely they will return to the activities. Continuing injury to natural resources used for subsistence may affect the way of life of entire communities.

Recovery Objective: Subsistence will have recovered when injured subsistence resources are healthy and productive and exist at pre-spill levels and people are confident that the resources are safe to eat. One indication that recovery has occurred is when the cultural values provided by gathering, preparing, and sharing food are reintegrated into community life.

RECOVERY MONITORING STRATEGY: Other than completion of laboratory sample analysis and result reporting to Native Villages, no new samples will be collected through FY 95. Harlequin duck and harbor seal monitoring studies (See each resource above.) are important for promoting confidence of subsistence users in wild foods.

Monitoring Schedule: See above.

Estimated Recovery Time: To be determined

RESEARCH AND GENERAL RESTORATION STRATEGIES: Some research and general restoration strategies intended to restore subsistence are included under the individual commercial fishing resources including pink salmon, sockeye salmon, herring, and harbor seals.

Other Research Priorities for FY 95 include clam recruitment projects. Subsistence users are reporting smaller and fewer clams at some sites previously used for subsistence gathering.

General Restoration Priorities for FY 95 include completion of 94279, Subsistence Food Safety Testing, including laboratory analysis of 1994 samples. Result reporting through newsletters and community follow-up meetings will be needed to accomplish the goals of this project. The newsletter will include all that was reported in other Trustee Council sponsored projects that have information which applies to subsistence communities.

Project 94272, Chenega Chinook Salmon Release, will continue for another four years. Project 94244, Harbor Seal and Sea Otter Cooperative Subsistence Harvest Assistance, will need to continue in order to meet project goals.

Subtidal Organisms

Recovery Status: Certain subtidal organisms, like eelgrass and some species of algae, appeared to be recovering. Other subtidal organisms, like leather stars and helmet crabs, showed little signs of recovery.

Recovery Objective: Subtidal communities will have recovered when the community composition, age class distribution, population abundance of component species, and ecosystem functions and services in each injured subtidal habitat have returned to levels that would have prevailed in the absence of the oil spill.

RECOVERY MONITORING STRATEGY: Focus on the eelgrass community in Prince William Sound. A matched-pair design is recommended.

Monitoring Schedule: Eelgrass sites should be monitored in 1995. Further monitoring should be dependent upon the results of this 1995 effort.

Estimated Recovery Time: Unknown

RESEARCH: The high-priority research issues for the nearshore ecosystem, including intertidal and subtidal organisms, are entirely ecosystem process questions. See Chapter 3: Nearshore Ecosystem, and Community Structure. See also discussion of other factors — predation, competition, and climatic/oceanographic factors.

GENERAL RESTORATION: No general restoration strategies have yet been identified for the 1995 Work Plan.

Appendix C

RECOVERY STATUS AND RECOVERY OBJECTIVE: SUBSTANTIVE CHANGES NOT IN APPENDIX B

Some workshop participants suggested changes in the Recovery Status and Recovery Objective for a resource or service. These had previously been subjected to independent peer review. Most of the recommended changes clarified these objectives, and thus are included in Appendix B. Those that substantively changed previous scientific conclusions are not included in this document but are being deferred pending further peer review. In some cases, you will receive a call asking for further information about your recommendation. This review process will be accomplished during the next several months.

This appendix lists those objectives and status statements that we excluded (based on Dr. Spies' recommendations). While no one has to do anything about them at this moment, they are hereby recorded or they would be lost and excluded.

Recovery Objectives & Status Statements Needing Further Review
"Yes" means they were excluded from Appendix A of the *Invitation*

Resource or Service	Recovery Status	Recovery Objective
Archaeology	Yes	Yes
Bald Eagle	Yes	Yes
Black Oystercatcher	Yes	
Cutthroat Trout	Yes	
Dolly Varden	Yes	
Herring Bay Intertidal	See Note #1	See Note #1
Intertidal Organisms	Yes	Yes
Killer Whale	Yes	
Persistence of Oil	See Note #2	See Note #2
Persistence of Oil (Mussels)	See Note #2	See Note #2
Persistence of Oil (Subtidal)	See Note #2	See Note #2
Pigeon Guillemot		Yes
Pink Salmon		Yes
Sea Otters	Yes	Yes
Subtidal Organisms	Yes	

Note #1: Herring Bay Intertidal Organisms was submitted as a new recovery monitoring category and was not included in Appendix A.
Note #2: These were included in Appendix A, but they are new categories and have never been reviewed (or at least agreed-upon).

Archaeological Resources

Recovery Status: Archaeological resources are nonrenewable: they cannot recover in the same sense as biological resources. The standard restorative approach to archaeological sites in federal law (e.g., ARPA) is through compensation of loss through data recovery combined with other mitigative actions (e.g., site stabilization, education, site patrols).

Recovery Objective: Archaeological resources will be considered recovered when spill-related injury ends; looting and vandalism are at or below pre-spill levels; and upon completion of the necessary compensatory data recovery (including analysis and report-writing in accordance with professional, federal, and state legal standards) and/or other mitigative actions.

Bald Eagles

Recovery Status: Up to 900 bald eagles may have been killed throughout the spill area. Estimates made in 1989, 1990, and 1991 indicate that there was not a significant increase in the PWS bald eagle population since the previous survey conducted in 1982. Productivity of Prince William Sound eagles was low in 1989, but appeared to have recovered by 1990.

Recovery Objective: Bald eagles will have recovered when Prince William Sound population trends are stable or increasing compared to previous data, and productivity is within normal bounds.

Black Oystercatcher

Recovery Status: The oiled population of black oystercatchers has not yet recovered. Productivity of black oystercatchers is recovering, although chick growth rates are still low in the oiled area. Oystercatchers may still be exposed to hydrocarbons when feeding in intertidal areas.

Cutthroat Trout

Recovery Status: Cutthroat trout have grown more slowly in oiled areas than in unoiled areas.

Dolly Varden

Recovery Status: Dolly Varden have grown more slowly in oiled areas than in unoiled areas.

"Herring Bay Intertidal Organisms" is a new category

Herring Bay Intertidal Organisms

Recovery Status: The lower intertidal zone and, to some extent, the middle intertidal zone are recovering. However, injuries persist in the upper intertidal zone, especially on rocky sheltered shores. Recovery of this zone appears to depend, in part, on the return of adult Fucus in large numbers.

Recovery Objective: Intertidal communities in the upper intertidal zone will have recovered when community composition, population abundance of component species, and ecosystem functions and services in each injured intertidal habitat have returned to levels that would have prevailed in the absence of the oil spill.

RECOVERY MONITORING STRATEGY: The strategy for this area represents a mix of recovery monitoring activities and activities to determine processes limiting recovery. The recovery monitoring component represents a minimal addition to the costs of the restoration research component which needs to be done on an annual basis. The recovery monitoring component should only be carried out if the restoration research component is conducted. The recovery monitoring provides a general control for the array of research activities.

Monitoring Schedule: Annual

Estimated Recovery Time: Unknown

Intertidal Organisms

Recovery Status: Some species showed evidence of recovery, but intertidal as a whole had not recovered as of the last sampling in 1991, in any habitat or region studied.

Recovery Objective: Intertidal communities in the upper intertidal zone will have recovered when community composition, population abundance of component species, and ecosystem functions and services in each injured intertidal habitat have returned to levels that would have prevailed in the absence of the oil spill.

Killer Whales

Recovery Status: Fourteen killer whales disappeared from the resident AB pod in Prince William Sound between 1989 and 1991. In 1992 and 1993, no additional whales were reported as missing. No additional whales were reported as missing. No births occurred in 1989 and 1990. A total of four calves have been born into AB pod since 1991 (one in 1991, two in 1992, and one in 1993). In 1988, the pod contained 36 whales; in September 1993, the pod contained 26 whales. The injured pod is growing again.

All New

Persistence of Oil (Intertidal Sediments, Mussels)

Oil itself is not an injured resource or service. It is the cause of the injuries. Monitoring the fate and persistence of oil in the environment including location, concentration, and toxicity provides foundation monitoring for remaining oil contamination in the ecosystem. It also provides specific recovery monitoring for continued contamination in sediments and mussels.

Recovery Status:

- *Prince William Sound.* Limited shoreline surveys and limited clean-up work occurred in 1991, 1992, and 1993. The surveys indicated that subsurface oil remained at many sites that were heavily oiled in 1989.

  In 1993, shoreline assessment surveys were conducted at over 75 sites in Prince William Sound. They found that oil residue was present at most sites and sheening occurred at some. They also found that surface oiling has become very stable. There was no measurable reduction in surface asphalt and surface oil residue from 1992 to 1993. Subsurface oiling, on the other hand, has decreased substantially since 1991. Overall, the amount of subsurface oil found at the study sites in 1993 is about 45% of the amount found in the same areas in 1991.

- *Kodiak.* No sites have been surveyed on Kodiak Island since 1990.

- *Alaska Peninsula.* No general assessment work has been done since 1990. Five study sites were established in 1992 to examine the persistence and degradation of oil along national park coast lines. Those sites will be revisited in 1994. The 1992 observations indicate a continuing presence of oil at those sites.

- *Cook Inlet and Outer Kenai Coast.* Only limited assessment work has been done since 1990. A study site was established in 1992 to examine the persistence and chemical degradation of oil along national park coast lines. That site will be revisited in 1994. The 1992 observation indicates a continuing presence of oil at that site.

Recovery Objective: With respect to residual oil contamination, recovery has been achieved when remaining oil concentrations are reduced to a level comparable to pre-spill levels.

Persistence of Oil (Mussel Beds)

Recovery Status: Mussels themselves are an injured resource, both from the recreational and subsistence view plus possibly being the vehicle for transferring petroleum hydrocarbons to higher consumers. High concentrations of petroleum PAH's remain evident in some mussel beds within Prince William Sound (PWS), and preliminary results indicate contaminated beds outside PWS also.

Recovery Objective: Recovery will be complete when sediment PAH concentrations have declined to pre-spill concentrations.

RECOVERY MONITORING STRATEGY: Beds identified as contaminated should be monitored no more than once every three years. In order to maintain a level effort of work, one-third of these beds could be monitored each year.

Persistence of Oil (Subtidal Sediments)

Recovery Status: All New Subtidal organisms living in or on sediments and demersal fish that forage in subtidal sediment habitats may be exposed to the petroleum hydrocarbons that may be contaminating the sediments. In 1991, shallow subtidal PAH composition patterns consistent with that of weathered *Exxon Valdez* oil (EVOS) were found mainly at Northwest Bay in the depth range 3 - 20 m. Reduced concentrations of EVO were found at some shallow water stations in Bay of Isles, Herring Bay, and Snug Harbor. Data in 1992 and 1993 on the fish exposed showed evidence of continued contamination.

Recovery Objectives: Subtidal sediments will have recovered when concentrations of petroleum hydrocarbons in shallow (0 - 20 m) sediments approximate the petrogenic background concentration that prevailed prior to the *Exxon Valdez* oil spill and petroleum exposure indices in biota from oiled sites are similar to indices in biota from non-oiled sites.

Pigeon Guillemot

Recovery Objective: Pigeon guillemots will have recovered when the Prince William Sound shows an increasing trend.

Pink Salmon

Recovery Objective: Pink salmon will have recovered when populations are healthy and productive. Indicators of recovery are (1) egg survivals in oiled areas are equivalent to pre-spill levels or levels in unoiled areas; and (2) pink salmon escapement goals are met and returns per spawner equal or exceed the pre-spill historic average.

Sea Otters

Recovery Status: Sea otters do not appear to be recovering in all areas affected by the spill. They may have suffered sublethal effects and may be receiving continued exposure to residual oil. Although injuries appear to be subsiding (based on mortality rates and patterns), recovery has not been demonstrated. An additional concern is the apparent limited reoccupation by sea otters of heavily-impacted habitat.

Recovery Objective: Sea otter recovery will be assumed when no significant changes in abundance are detected over five surveys in the heavily oiled area and when densities do not differ between heavily oiled and non-oiled areas and when mortality patterns appear normal.

Subtidal Organisms

Recovery Status: Through 1991, certain subtidal organisms, like eelgrass and some species of algae, appeared to be recovering. Other subtidal organisms, like leather stars and helmet crabs showed little signs of recovery. Recent observations suggest that eelgrass habitat may not be recovering.

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Appendix D

LIST OF WORKSHOP PARTICIPANTS

The individuals listed in this appendix participated in a workshop sponsored by the Trustee Council in Anchorage, April 13-15, 1994. These individuals worked together to identify and prioritize research and monitoring issues needed for the 1995 restoration program.

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Appendix E
MEETING AGENDA

Research Priorities For Restoration

Anchorage, April 13-15, 1994

April 13 Part 1. Guidance for the 1995 Work Plan and Beyond

0830 Science Planning and Management for the Restoration Process
Jim Ayers, Executive Director for the Trustee Council

0900 Ecosystem Approach to Restoration
Dr. George Rose, OPEN Scientific Program Leader(if available)

0945 Game Plan for the Workshop: Part 1
Molly McCammon, Operations Director for the Trustee Council

0955 BREAK

1015 Directing the Research: Examples of Hypotheses
Presentations by the Members of the Interdisciplinary Work Groups

1200 LUNCH

1300 Interdisciplinary Work Groups Meet
- Selection of Coordinating Committee Representative
- Development of hypotheses list

1700 BREAK

1900 Interdisciplinary Work Groups Meet
- Continued development of hypotheses list

April 14

0830 Meeting of the Whole
- Coordinating Committee Representatives present hypotheses from Work Groups
- Discussion of classification of hypotheses by ecosystem component (nearshore, pelagic) and/or type of hypotheses (e.g., ecosystem processes, ecotoxicology)

1000 BREAK

1020 Interdisciplinary Work Groups Meet
- Classify, prioritize hypotheses

1200 Working Lunch

1400 BREAK

1430 Meeting of the Whole
- Coordinators present draft final lists for review by participants
- Revised lists are compiled as draft for mail-out review

1600 How We Get There From Here
Jim Ayers, Executive Director

April 15 Part 2. Revision of The Draft Restoration Plan

0830 Management By Objective: Strategies for Restoration
Jim Ayers, Executive Director

0900 Game Plan for the Workshop: Part 2
Molly McCammon, Operations Director

0910 Monitoring Strategies for the Restoration Plan
Byron Morris, NOAA

0935 Research/Restoration Strategies for the Restoration Plan
Veronica Gilbert, Alaska Department of Natural Resources

1000 BREAK

1020 Interdisciplinary Work Group Meetings
- Review Monitoring, Research, and Restoration Strategies
- Provide comments and revisions for inclusion in DEIS review document

1200 Working Lunch

1430 Revising the Injured Resource Listing
Bob Spies, Chief Scientist for the Trustee Council

1700 Closing Comments
Jim Ayers, Executive Director