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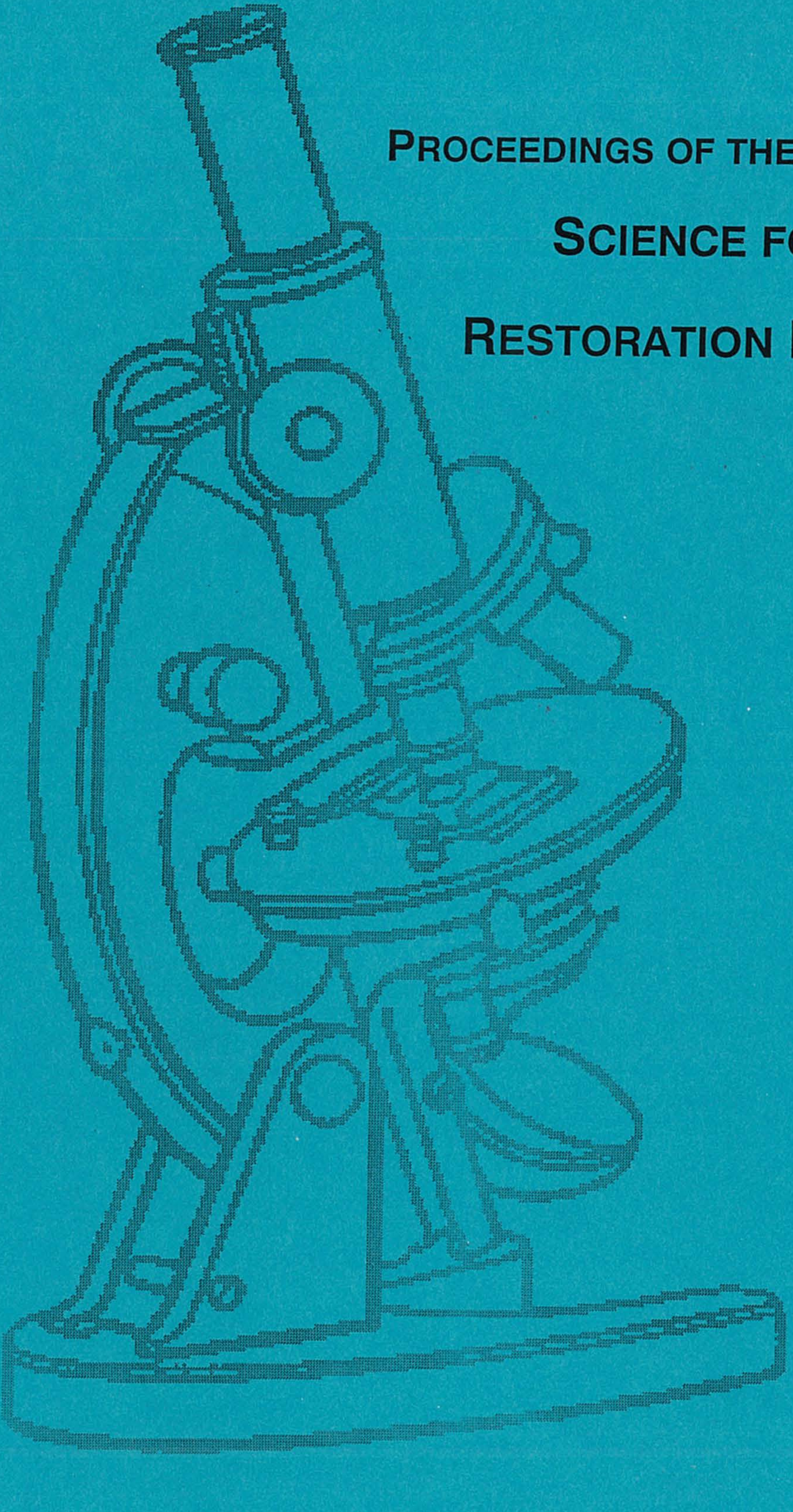
Proceedings of the Workshop

Science for the Restoration Process



Exxon Valdez Trustee Council
Anchorage, Alaska
April 13-15, 1994

ACKNOWLEDGEMENTS

WORKSHOP ORGANIZATION

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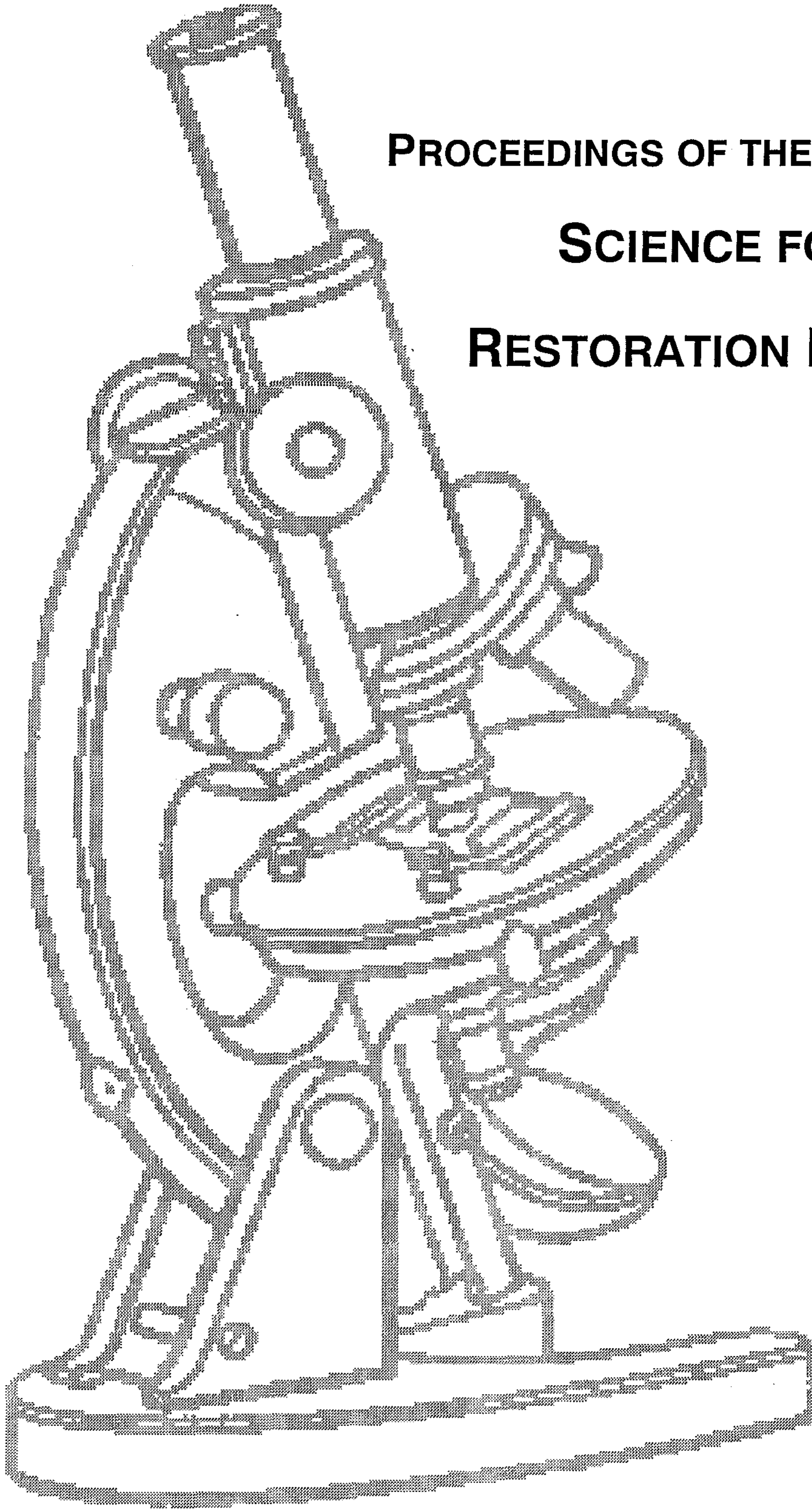
WORKSHOP PARTICIPANTS

Special thanks to all participants listed in Appendix D



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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 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. Causes for the failure of Prince William Sound herring and pink salmon production: pelagic ecosystem component.

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

3. Alteration of nearshore community structure: nearshore ecosystem component.

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

5. Alteration of zooplankton community structure in impacted sockeye salmon rearing lakes: 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.

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Science for the Restoration Process

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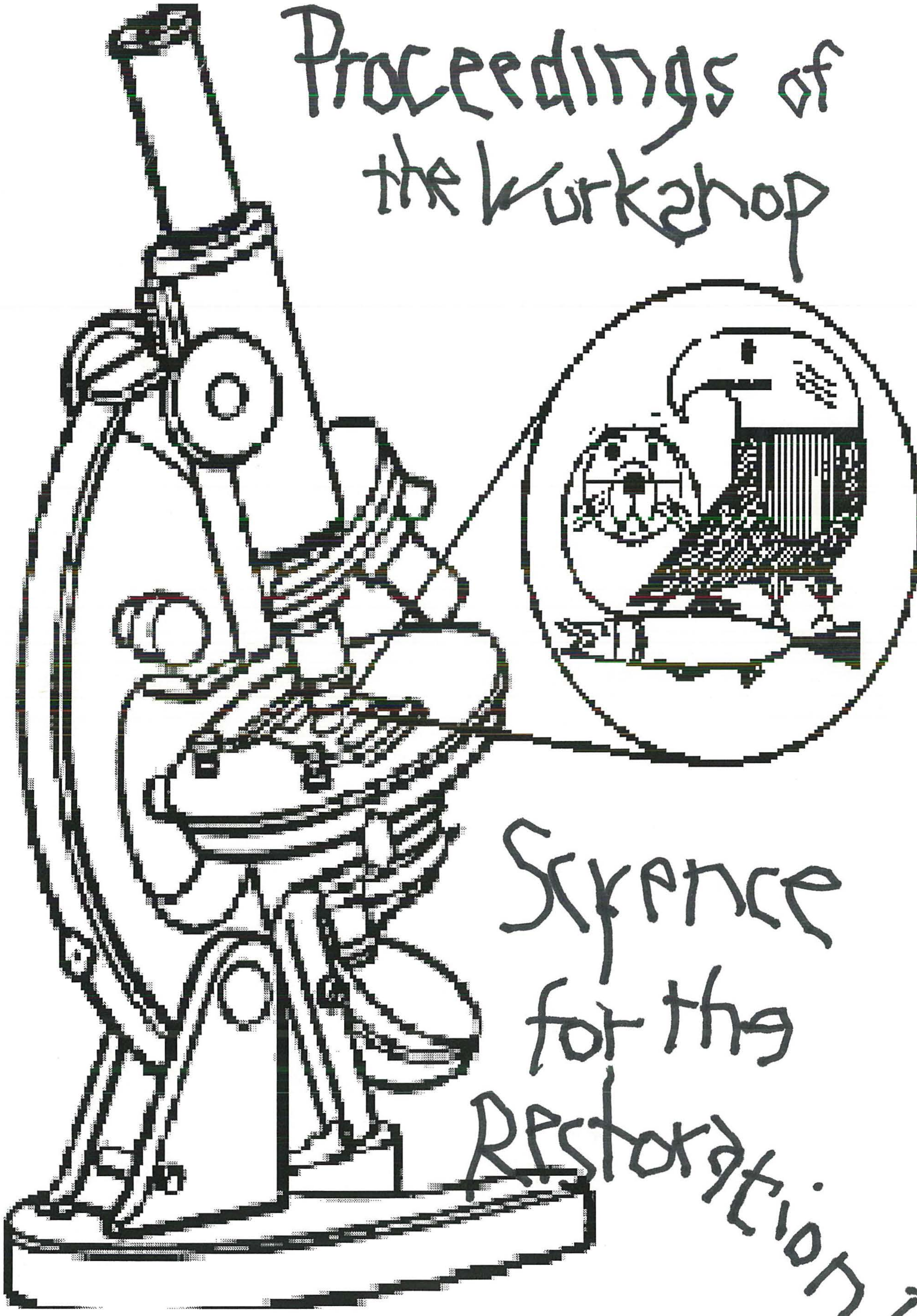

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