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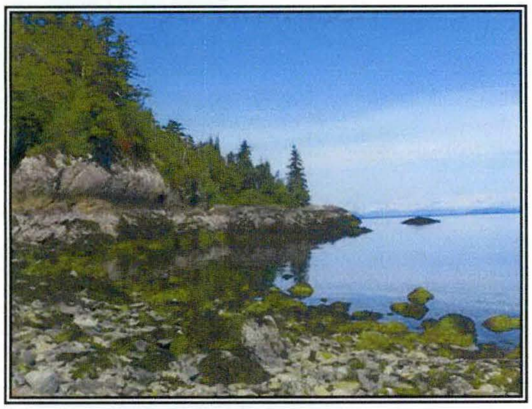

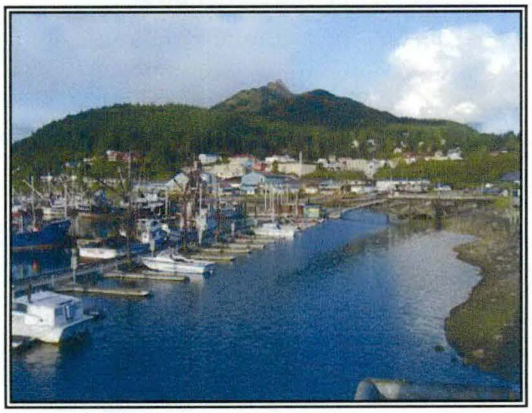

Exxon Valdez Oil Spill Restoration Plan

2009 UPDATE INJURED RESOURCES AND SERVICES

DRAFT - December 31, 2008

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2009 Update on Injured Resources and Services

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2009 Update on Injured Resources and Services

INTRODUCTION

Purpose of the Injured Resources and Services List

In November 1994, the *Exxon Valdez* Oil Spill Trustee Council adopted an official list of resources and services injured by the Spill as part of its Restoration Plan[1]. The Injured Resources and Services List (List) serves three main purposes in the Restoration Program:

1. Initially, the List identified natural resource and human service injuries caused by the oil spill and clean-up efforts.

2. The List helped guide the *Restoration Plan* and was especially important in 1994 when the plan was first adopted. The List was created as guidance for the expenditure of public restoration funds under the Plan, and assisted the Trustees and the public with ensuring that money was expended on resources that needed attention. The List continues to serve that purpose today.

3. Finally, the status of injured resources on the List provides the Trustees and the public a way to monitor recovery of ecological functions and human services that depend on those resources.

Although the fish and wildlife resources that appear on the List experienced population-level or chronic injury from the spill, not every species that suffered some degree of injury was included. For example, carcasses of about 90 different species of oiled birds were recovered in 1989, but only 10 species of birds were included on the List.

Moreover, it should be noted that the analysis of resources and services in relation to their recovery status only pertains to amelioration of effects from the 1989 oil spill. When the Restoration Plan was first drafted, the distinction between effects of the oil spill and the effects of other natural or anthropogenic stressors on affected natural resources was not clearly delineated. At that time, the spill was recent; the impact to the spill area ecosystem was profound and adverse effects of the oil on biological resources were apparent. As time passes, the ability to distinguish effects of oil from other factors affecting fish and wildlife populations diminishes. Currently, natural and human perturbations may be hindering recovery of some resources initially injured by the spill. While those perturbations warrant consideration in defining and assessing recovery, they do not negate the responsibility of the Trustee Council to pursue restoration of spill-affected resources.

Restoration Goals and Objectives

The *Restoration Plan* guides the Trustee Council's restoration efforts with respect to resources and services in the spill-affected area (Figure 1)

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[1] *www.evostc.state.ak.us/Policies/restplan.htm*

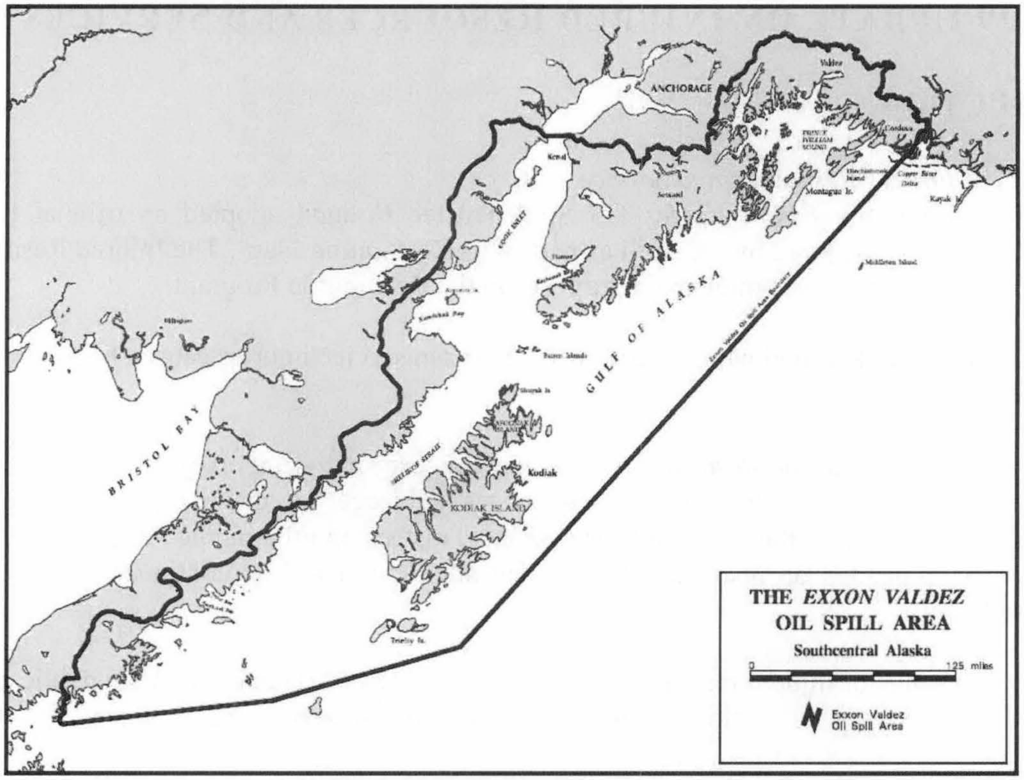

Figure 1: Map produced by: Alaska Department of Natural Resources, Land Records Information Service

It contains policies for making restoration decisions and describes how restoration actions will be implemented. As part of the *Restoration Plan*, the List was created to document injured resources that were of concern to the Trustee Council. The following benchmarks were established to assess the status of the resources and services injured by the oil spill:

- **Restoration Goal:** The overarching goal of the Restoration Program is the recovery of all injured resources and services, sustained by healthy, productive ecosystems to maintain naturally occurring diversity.

- **Recovery Goal of Injured Resources and Services:** The primary goal for all recovering injured resources and services is a return to conditions that would have existed had the spill not occurred.

- **Recovery Objective/s:** Specific, measurable parameters that, when achieved, signal the recovery of an injured resource or service.

- **Restoration Strategy:** The restoration strategy is a plan of action adopted by the Trustee Council to achieve recovery objectives.

It is difficult to predict conditions that would have existed in the absence of the spill. Therefore, the recovery objectives include measurable and biologically substantive parameters that can be used as proxies for these conditions. In some cases, multiple objectives are used for individual resources. For some resources, so little is known about the original or current injury or status that identifying a recovery objective has not been possible.

In the 2006 Update[2] to the List, the following factors were considered in the development of the Recovery Objectives established for injured resources:

- Return to pre-spill levels: Used where population estimates or indices were available prior to 1989. For species that are highly variable, these numbers could reflect a range of values. Where possible, these numbers account for the effects of other influences on injured populations, such as from climate change, although these other effects may interact with oil spill effects.

- Hydrocarbon exposure: Used where hydrocarbon exposure itself was part of the original basis for injury, where hydrocarbon exposure may limit recovery, or where hydrocarbon exposure in an injured resource may be a pathway to injury in other resources. Oil exposure may refer to background concentrations, which takes into account hydrocarbon exposure from natural oil seeps, natural coal deposits, and oil released from the Valdez petroleum plant as a result of the 1964 earthquake.

- Stable or increasing population: Used where resources were in decline before the spill or where ongoing declines unrelated to the spill may be occurring.

- Productivity: Reproductive success and population demographics are used in lieu of or to supplement data on population sizes. Measures include such indicators as eggs produced per female, young successfully reared, returns per spawning adult and growth rates.

In the 2009 List, the objectives were updated to address:

- Stressors other than oil that may be currently affecting a population.

- The likelihood that a resource has recovered given the amount of time that has lapsed since the spill.

- Changes to the environment in Prince William Sound since 1989 may make returning some resources to pre-spill levels unlikely.

- The addition of Barrow's goldeneyes to the List.

Recovery Status Categories:
The List has historically included four categories of recovery which are defined below. The categories represent a scale along which an injured resource can progress:

- **Not Recovering**: Resources that are not recovering continue to show little or no clear improvement from injuries stemming from the oil spill. Recovery objectives have not been met.

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[2] *http://www.evostc.state.ak.us/Publications/injuredresources.cfm*

- **Recovering:** Recovering resources are demonstrating substantive progress toward recovery objectives, but are still adversely affected by residual impacts of the spill or are currently being exposed to lingering oil. The amount of progress and time needed to attain full recovery varies depending on the species.

- **Recovered:** Recovery objectives have been met, and the current condition of the resource is not related to residual effects of the oil spill.

- **Recovery Unknown:** For resources in the unknown category, data on life history or the extent of injury from the spill is limited. Moreover, given the length of time since the spill, it is unclear if new or further research will provide information that will help in comprehensively assessing the original injury or determining the residual effects of the spill such that a better evaluation of recovery can occur.

Human services that rely on natural resources were also injured by the oil spill and can thus be placed in one of the above categories. Because the recovery status of injured services is inextricably linked to the state of the resource on which it depends, full recovery of the spill area can not occur until both resources and services are restored.

Update History: The *Restoration Plan* states that the List should be reviewed periodically and updated to reflect results from scientific studies and other information. A summary of how the list has changed since 1996 is available in Table 1.

A reassessment of the List is necessary to understand the consequences of the original spill and the effects of oil remaining in the environment. It also provides a way to identify areas where additional restoration activities are needed and documents each resource's progress toward its recovery objectives.

The List was first updated in September 1996. At that time, the bald eagle was upgraded from recovering to recovered. In March 1999, a major review of recovery objectives and status occurred and several more changes were made. River otters were then considered to be recovered, and five resources—black oystercatchers, clams, marbled murrelets, Pacific herring, and sea otters—were upgraded to recovering. One resource, the common loon, was moved from recovery unknown to not recovering. Five resources remained as recovery unknown. All four human services were classified as recovering.

Recovery continued to progress and more changes were made to the List in 2002. Five more species or resources were moved to the recovered category: archaeological resources, black oystercatchers, common murres, sockeye salmon and pink salmon. In addition, designated wilderness areas were moved from the recovery unknown to the recovering category; Pacific herring were moved back from the recovering to the not recovering category; subtidal communities were moved from the recovering to recovery unknown category; and killer whales were moved from not recovering to recovering. In all, seven resources were considered fully recovered from the effects of the oil spill; 16 resources and all four human services were not fully recovered; and the recovery of five resources was still considered unknown.

In 2006, the update acknowledged the recovery of common loons, cormorants, Dolly Varden, and harbor seals from the effects of the spill. Harlequin ducks were moved from not recovering to recovering based on positive population trends, and marbled murrelets were moved from recovering to unknown.

Table 1: Historical and current overview of the status of injured resources and services during each reassessment year.

Resource	1996 Status	1999 Status	2002 Status	2006 Status	2009 Status
Archaeological Resources	Recovering	Recovering	Recovered	Recovered	Recovered
Bald Eagles	Recovered	Recovered	Recovered	Recovered	Recovered
Barrows goldeneyes	N/A	N/A	N/A	N/A	Recovering
Black Oystercatchers	Unknown	Recovering	Recovered	Recovering	Recovering
Clams	Unknown	Recovering	Recovering	Recovering	Recovering
Common Loons	Unknown	Not Recovering	Not Recovering	Recovered	Recovered
Common Murres	Recovering	Recovering	Recovered	Recovered	Recovered
Cormorants	Not Recovering	Not Recovering	Not Recovering	Recovered	Recovered
Cutthroat Trout	Unknown	Unknown	Unknown	Unknown	Unknown
Designated Wilderness	Unknown	Unknown	Recovering	Recovering	Recovering
Dolly Varden	Unknown	Unknown	Unknown	Recovered	Recovered
Harbor Seals	Not Recovering	Not Recovering	Not recovering	Recovered	Recovered
Harlequin Ducks	Not Recovering	Not Recovering	Not recovering	Recovering	Recovering
Intertidal Communities	Recovering	Recovering	Recovering	Recovering	Recovering
Killer Whales	Not Recovering	Not Recovering	Recovering	Recovering	Recovering
Kittlitz's Murrelets	Unknown	Unknown	Unknown	Unknown	Unknown
Marbled Murrelets	Not Recovering	Recovering	Recovering	Unknown	Unknown
Mussels	Recovering	Recovering	Recovering	Recovering	Recovering
Pacific Herring	Not Recovering	Recovering	Not recovering	Not recovering	Not recovering
Pigeon Guillemots	Not Recovering	Not Recovering	Not recovering	Not recovering	Not recovering
Pink Salmon	Recovering	Recovering	Recovered	Recovered	Recovered
River Otters	Unknown	Recovered	Recovered	Recovered	Recovered
Rockfish	Unknown	Unknown	Unknown	Unknown	Unknown
Sea Otters	Not Recovering	Recovering	Recovering	Recovering	Recovering
Sediments	Recovering	Recovering	Recovering	Recovering	Recovering
Sockeye Salmon	Recovering	Recovering	Recovered	Recovered	Recovered
Subtidal Communities	Recovering	Recovering	Unknown	Unknown	Unknown

Human Service	1996 Status	1999 Status	2002 Status	2006 Status	2009 Status
Commercial Fishing	Recovering[a]	Recovering	Recovering	Recovering	Recovering
Passive Use	Recovering[a]	Recovering	Recovering	Recovering	Recovering
Recreation & Tourism	Recovering[a]	Recovering	Recovering	Recovering	Recovering
Subsistence	Recovering[a]	Recovering	Recovering	Recovering	Recovering

[a] *Classified as "Lost or Reduced Service" in 1996 Update, meaning that the service was negatively indirectly impacted by the spill due to its connection with impacted natural resources*

Twenty years after oil spill, we are again evaluating the status of injured resources and services and providing a synopsis of the most current information available in the updated List. Based on the recommendations from the Science Panel and agency experts, the recovery objectives have been reviewed for each resource and service to ensure that the objectives are attainable and scientifically valid. Also, Barrows goldeneyes have been added to the list for the first time based on their continuing exposure to oil.

Recovery Status Determination
The recovery goal for injured resources is a condition that would exist in the absence of the *Exxon Valdez* oil spill (EVOS). It is important to understand that ecosystems are dynamic and the spill-affected area would have changed even without the spill. Given our limited ability to predict multi-year changes in marine ecosystems, it is difficult to know precisely what changes were inevitable had the spill not occurred. However, it is still possible to assess the recovery status of a particular resource by reviewing multiple sources of applicable information.

Types of information that were used to assess the recovery status of a particular resource or service included:

- initial magnitude of oil impacts to a population in the spill area
- comparisons of population demographic in oiled and reference areas
- survey data of community members in oiled and reference areas
- continued exposure to residual oil in the spill area as measured by the biomarker cytochrome P450 or tissue concentrations of petroleum hydrocarbons
- exposure potential as evaluated by the distribution of lingering oil; overlap in spatial distribution of lingering oil and a resource; and identification of an exposure pathway
- persistence of sublethal or chronic injuries
- intrinsic ability of the population to recover
- other natural or human-caused stressors

Even with such an evaluation, direct links cannot always be drawn between effects from the oil spill and the observed, current condition of a particular resource: in most cases the amount or type of data is insufficient to complete a cause and effect relationship. Specifically, we have little pre-spill data for many of the injured resources. Moreover, the physiological effects of oil on key species of wildlife and subsequent population consequences were not well understood at the time of the spill. As a result, few species exist for which we have complete knowledge of the original impacts of the oil spill. To mitigate the uncertainties inherent in evaluating recovery we reviewed current, relevant scientific information while acknowledging the limitations of assigning an ultimate cause and effect relationship using the existing data. The types of uncertainty found in the literature include:

1. *Variability in population estimates*. Because the patterns of animal distribution present challenges in getting accurate counts (especially of highly mobile fish, birds and marine mammals), most estimates of population size have wide ranges of variability associated with the data.

2. *Lack of pre-spill data*. Many of the resources affected by the spill had limited or no recent data on their status in 1989. Additionally, some of the available pertinent data were the result of limited sampling, which consequently produced wide confidence intervals around the population estimates.

3. *Interaction of spill and natural factors*. It is increasingly difficult to separate what may be lingering effects of the spill from changes that are natural or caused by factors unrelated to the oil spill.

4. *Scale.* The geographic scale of studies conducted over the years has varied among resources and this disparity must be considered when interpreting data and applying results to recovery status. Some studies were conducted at the large spatial scale to address population and ecosystem concerns, while other studies focused on localized exposure and effects of oil.

Ecosystem Perspective and Recovery
The List consists mainly of single species and resources, but it provides a basis for evaluating the recovery of the overall ecosystem; its functions and the services it provides to people. In fact, through the *Restoration Plan*, the Trustee Council adopted an ecological approach to restoration, and the studies and projects the Trustee Council sponsors have been ecologically-based.

The *Restoration Plan* defines ecosystem recovery as follows:

> *Full ecological recovery will have been achieved when the population of flora and fauna are again present at former or pre-spill abundances, healthy and productive, and there is a full complement of age classes at the level that would have been present had the spill not occurred. A recovered ecosystem provides the same functions and services as would have been provided had the spill not occurred.*

Although significant progress has been made, using this definition of recovery, the coastal and marine ecosystems in the oil spill region have not fully recovered at this time from the effects of the oil spill. For example, harlequin ducks still show signs of oil exposure and may be negatively affected by such exposure. A number of other species and communities are showing signs of recovery, but are still not fully recovered from the effects of the oil spill. Although full ecological recovery has not been achieved, the spill area ecosystem is making progress towards recovery 20 years after the *Exxon Valdez* oil spill.

INJURED RESOURCES

ARCHAEOLOGICAL RESOURCES

Injury
The oil spill area is believed to contain more than 3,000 sites of archaeological and historical significance. Twenty-four archaeological sites on public lands are known to have been adversely affected by clean-up activities or looting and vandalism linked to the oil spill. Additional sites on both public and private lands were probably injured, but damage assessment studies were limited to public land and not designed to identify all such sites.

Documented injuries included theft of surface artifacts, masking of subtle clues used to identify and classify sites, violation of ancient burial sites, and destruction of evidence in layered sediments. In addition, residual oil may have contaminated sites.

Recovery Objective
Archaeological resources are nonrenewable: they cannot recover in the same sense as biological resources. Archaeological resources will be considered to have recovered when spill-related injury ends, looting and vandalism are at or below pre-spill levels, and the artifacts and scientific data remaining in vandalized sites are preserved (e.g., through excavation, site stabilization, or other forms of documentation).

Recovery Status
Assessments of 14 sites in 1993 suggested that most of the archaeological vandalism that can be linked to the spill occurred early in 1989, before adequate constraints were put into place over the activities of oil spill clean-up personnel. Most vandalism took the form of "prospecting" for high yield sites. Once these problems were recognized, protective measures were implemented and successfully limited additional injury. Although some cases of vandalism were documented in the 1990s, there appears to be no spill-related vandalism at the present time.

From 1994-1997, two sites in Prince William Sound were partly documented, excavated, and stabilized by professional archaeologists because they had been so badly damaged by oiling and erosion. The presence of oil in sediment samples taken from four sites in 1995 did not appear to have been the result of re-oiling by Exxon Valdez oil. Residual oil does not appear to be contaminating any known archaeological sites.

In 1993, the Trustee Council provided part of the construction costs for the Alutiiq Archaeological Repository in Kodiak (www.alutiiqmuseum.com). This facility now houses Kodiak area artifacts that were collected during spill response. In 1999, the Trustee Council approved funding for an archaeological repository and local display facilities for artifacts from Prince William Sound and lower Cook Inlet. Local displays are open to the public in Port Graham, Cordova, Seward, Seldovia, and Tatitlek. The facility in Seward serves as the repository for the Chugach region.

Based on the apparent absence or extremely low rate of spill-related vandalism and the preservation of artifacts and scientific data on archeological sites, archaeological resources are considered to be recovered.

BALD EAGLES

Injury
The bald eagle is an abundant resident of marine and riverine shorelines throughout the oil spill area. Following the oil spill, a total of 151 eagle carcasses were recovered from the spill area. Prince William Sound provides year-round and seasonal habitat for about 6,000 bald eagles, and within the Sound it is estimated that about 250 bald eagles died as a result of the spill. There were no estimates of mortality outside the Sound, but there were deaths throughout the spill area. In addition to direct mortalities, productivity was reduced in oiled areas of Prince William Sound in 1989.

Recovery Objective
Bald eagles will have recovered when their population and productivity (reproductive success) have returned to pre-spill levels.

Recovery Status
Productivity (or reproductive success as measured by chicks per nest) was back to pre-spill levels in 1990 and 1991, and an aerial survey of adults in 1995 indicated that the population had returned to or exceeded its pre-spill level in the Sound.

In September 1996, the Trustee Council classified the bald eagle as recovered from the effects of the oil spill.

BARROW'S GOLDENEYES

Injury

Barrow's goldeneyes are sea ducks that winter in protected nearshore marine waters in Prince William Sound and feed in the intertidal zone, consuming mussels, aquatic insects, fish and fish eggs.

Some acute mortality of Barrow's goldeneyes was observed in the weeks and months immediately following the *Exxon Valdez* oil spill in March 1989. Total acute mortality of Barrow's goldeneyes is difficult to determine, given uncertainty in carcass identification and recovery rates, but sea ducks, generally, were vulnerable to acute mortality and constituted approximately 25percent of the carcasses recovered in Prince William Sound. Given the number of Barrow's goldeneyes present at the time of the spill, acute mortality was likely in the thousands.

Of more concern are longer-term effects due to either chronic exposure to lingering oil or indirect effects of trophic web disruption. Because Barrow's goldeneyes occur exclusively in intertidal and shallow subtidal habitats, they would be particularly vulnerable to effects of lingering oil. Similarly, reliance on intertidal invertebrate prey would suggest that Barrow's goldeneyes are particularly vulnerable to disruptions of intertidal communities. Barrow's goldeneyes have been shown to have higher levels of induction of cytochrome P4501A (CYP1A) in oiled areas compared to unoiled areas. Elevated CYP1A induction in Barrow's goldeneyes from oiled areas of Prince William Sound was documented in 1997 and 2005. While these do not necessarily demonstrate subsequent injury, the potential for individual- or population-level effects of exposure to residual oil is plausible.

Recovery Objective

Barrow's goldeneyes will have recovered when breeding- and nonbreeding-season demographics and biochemical indicators of hydrocarbon exposure in goldeneyes in oiled areas of Prince William Sound are similar to those of goldeneyes in unoiled areas.

Recovery Status

Within their wintering range, Prince William Sound is an important area, supporting between 20,000 and 50,000 wintering individuals. Survey data from the U.S. Fish and Wildlife Service indicated that winter numbers of goldeneyes on oiled areas were stable from 1990-1998, in contrast to significantly increasing numbers on unoiled areas during that same time period. That was interpreted as evidence of lack of recovery, as the prediction would be that lack of continued injury would result in parallel population trajectories and that recovery would be indicated by more positive trajectories on oiled areas. In the most recent published survey (through March 2005), slopes were parallel and stable over time, although this was due primarily to a decrease in goldeneye abundance on unoiled areas.

A study of Barrow's goldeneye habitat use in oiled and unoiled portions of Prince William Sound found that densities of birds in oiled areas were at expected levels, given the habitat, suggesting that the oil spill had not led to depressed numbers at the time of the study (1996 and 1997).

Interpretation of surveys and habitat selection is constrained by lack of full understanding of Barrow's goldeneye demography, particularly rates of site fidelity and dispersal. These values have important implications for understanding the process of population recovery.

The continued induction of CYP1A through March 2005 and the only recent lack of difference between oiled and unoiled areas, suggest that the Barrow's goldeneyes have not yet recovered from the effects of the oil spill.

BLACK OYSTERCATCHERS

Injury
Black oystercatchers spend their entire lives in or near intertidal habitats and are highly vulnerable to oil pollution. They are fully dependent on the nearshore environment and forage exclusively on invertebrate species along shorelines. It is estimated that 1,500-2,000 oystercatchers breed in south-central Alaska. Only nine carcasses of adult oystercatchers were recovered following the spill, but the actual number of mortalities may have been several times higher.

In addition to direct mortalities, breeding activities were disrupted by the oil and clean-up activities. When comparing 1989 with 1991, significantly fewer pairs occupied and maintained nests on oiled Green Island, while during the same two years the number of pairs and nests remained similar on unoiled Montague Island. Nest success on Green Island was significantly lower in 1989 than in 1991, but Green Island nest success in 1989 was not lower than on Montague Island. In 1989, chicks disappeared from nests at a significantly greater rate on Green Island than from nests on Montague Island. Disturbance associated with clean-up operations also reduced productivity on Green Island in 1990. In general, the overt effects of the spill and clean-up had dissipated by 1991, and in that year productivity on Green Island exceeded that on Montague Island.

Recovery Objective
Black oystercatchers will have recovered when the population, reproduction and productivity and oil exposure biomarkers are within normal bounds. An increasing population trend and comparable hatching success and growth rates of chicks in oiled and unoiled areas, after taking into account geographic differences, will indicate that recovery is underway.

Recovery Status
Black oystercatchers are long-lived (15+ years) and territorial, occupying nests in rocky areas close to the intertidal zone and returning in successive years to nest again in the same vicinity. In the early 1990s, elevated hydrocarbons in feces were measured in chicks living on oiled shorelines. Deleterious behavioral and physiological changes including, lower body weight of females and chicks were also recorded. Because foraging areas are limited to a few kilometers around a nest, contaminations of mussel beds in the local vicinity was thought to provide a source of exposure. In 1998 the Trustee Council sponsored a study to reassess the status of this species in Prince William Sound. The data indicated that oystercatchers had fully reoccupied and were nesting at oiled sites in the Sound. The breeding phenology of nesting birds was relatively synchronous in oiled and unoiled areas, and no oil-related differences in clutch size, egg volume, or chick growth rates were detected. However, a higher rate of nest failure occurred on oiled Green Island: At the time this was thought to be the result of predation, not lingering effects of oil. Because the extent of shoreline with persistent contamination was limited and lingering oil

was patchy, it was concluded that the overall effects of oil on oystercatchers in the Sound had been minimal. However, the reasons that predation was higher at oiled Green Island than at Montague were not investigated. It is not clear whether predation was higher because there were higher numbers of predators, lower number of nests initiated or a behavioral change in the parents that would have led to lower nest protection.

Based on this study and one year of boat-based surveys (2000) of marine birds in Prince William Sound indicating that there were increases in numbers of oystercatchers in both the oiled and unoiled areas for that year, the black oystercatcher was identified as recovered. Since 2002, however, additional information has come to light indicating that designation may have been premature. A long-term (1989 – 2005) evaluation of marine bird population trends suggest that populations of black oystercatchers in the Sound have likely not recovered to pre-spill conditions.
Further, ongoing oil exposure to oystercatchers was documented in 2004 using a biochemical marker of exposure, cytochrome P450IA. Given our more recent understanding of the persistence of oil in sediments along shorelines that initially received heavy or moderate oiling, it is likely that black oystercatchers in oiled areas have suffered chronic exposure as has been shown for sea otters and harlequin ducks. Hydrocarbon exposure in 2004 is likely considerably less than in the early 1990's, but at this time, we do not know if there are any significant physiological or population level consequences from chronic exposure.

Therefore, because population trends do not indicate recovery over 18 years of surveys, because a high rate of nest failure occurred in the oiled study area in the late 1990s, and because in 2004, continuing exposure of black oystercatchers to oil was reported, this species is listed as recovering.

CLAMS

Injury
Clams are widely distributed throughout the oil spill area. They can be found in a variety of substrates and are most abundant in the lower intertidal and subtidal zones. Clams are important prey for various fish and wildlife resources including sea otters, some sea birds, sea ducks and others.

The magnitude of the immediate impacts of oil on clam populations varied depending on species of clam, degree of oiling and location. Although direct mortality of some clam species like littlenecks and butter clams were assessed for several years after the spill, other more sensitive species, (e.g., *Macoma* and *Mya* spp) were not the focus of much study, and the immediate impact of the oil to these species remains unknown. In 1990 and 1991, growth of littleneck clams at oiled sites was less than at reference sites, and growth rate was directly proportional to hydrocarbon concentrations. Additionally, mortality was higher and growth rates lower in clams transplanted from oiled areas to clean areas, five to seven years after the spill.

Clean-up technologies were detrimental to clam populations, including hot water, high pressure washing, manual and mechanical scrubbing and physical removal of oiled sediments. Hot water washing caused thermal stress, oil dispersal into the water column, animal displacement and burial, and the transportation of fine grain sediment from the upper intertidal into the lower intertidal zone. Early assessments reported that clean-up activities resulted in reductions in clam abundance and distribution on treated (oiled-but-treated) beaches up to three years after the spill.

Recovery Objective

Clams will have recovered when population and productivity measures at oiled and washed sites are comparable to populations and productivity measures at unwashed sites, when there is no oil exposure, and when abundances of large clams can provide adequate, uncontaminated food supplies for predators and subsistence users.

Recovery Status

Studies have indicated that abundances of some species of clams were lower on treated beaches through 1996. Densities of littleneck and butter clams were depressed through 1997 on cleaned mixed-sedimentary shores where fine sediments had been washed down the beach during pressured water treatments.

As part of an investigation of sea otter populations conducted from 1996-1998, researchers compared clam densities between oiled sites on Knight Island and unoiled sites on Montague Island. They reported an increase in mean size of littlenecks and butter clams at Knight Island, where numbers of sea otters, a major predator of clams were significantly reduced. Absolute densities of littlenecks and butter clams were not different between oiled and unoiled sites; however, oiled sites had fewer juvenile clams and lower numbers of other clam species. In 2002, differences in species richness, diversity and abundance of several species were still measurable between cleaned (oiled and treated) and untreated (oiled but untreated) beaches. Moreover, as of 2005, several wildlife species that use the intertidal zone and feed on clams (e.g., harlequin ducks and black oystercatchers) are still being exposed to oil. These resources are included on the injured resources list and although the exact route of oil contamination has not been established for these birds, it is likely they are ingesting oil with their prey.

Some overlap occurs between areas where lingering oil and populations of littleneck and butter clams co-exist. Given the burrowing behavior of these animals, it is likely they would be exposed to oil as they dig into the subsurface sediments known to contain oil. In fact, it has been demonstrated that littleneck clams exposed for a year to the surface layer of contaminated sediments did not accumulate oil, but if the clams were buried in sediments mixed with oil, accumulation did occur.

Clam populations found on oiled but untreated beaches have likely recovered from the effects of the spill. However, several factors continue to impact clam populations on oiled and treated beaches: Abundances and distribution differences are still measurable between cleaned and untreated sites; Lingering oil occurs in habitats with clams, and exposure of clams to oil could result in upper trophic level predators eating contaminated prey and other species on the injured resources list are still being exposed to oil and are known to forage on clams.

Based on all of the evidence summarized above, clams continue to recover, but are not yet fully recovered from the effects of the oil spill.

COMMON LOONS

Injury
Carcasses of 395 loons of four species were collected following the spill, including 216 common loons. Current population sizes in the spill area are not known for any of these species, but it is estimated that the 216 collected common loons represented between 720 – 2,160 total individuals that died as a result of the initial oiling event. Common loons in the spill area may number only a few thousand, including only hundreds in Prince William Sound. Common loons injured by the spill probably included a mixture of wintering and migrating birds. The specific breeding areas used by the loons affected by the spill are not known.

Recovery Objective
Common loons will have recovered when their population returns to pre-spill levels in the oil spill area. An increasing population trend in Prince William Sound will indicate that recovery is underway.

Recovery Status
Boat-based surveys of marine birds in Prince William Sound give some insight into the recovery status of the loons affected by the oil spill. Pre-spill counts of loons exist only for 1972-1973 and 1984-1985. After the spill, contrasts between oiled and unoiled areas of the sound indicated that loons as a group were generally doing better in unoiled areas than in oiled areas. Thus, the survey data suggested that the oil spill had a negative effect on numbers of loons (all species combined) in the oiled parts of the Sound.

Common loons exhibited declines in population numbers and habitat usage in oiled areas in 1989 but not in 1990. There was a weak negative effect of oiling on population numbers again in 1993, but not in 1996 or 1998. Based on the boat surveys carried out through 2000, there were indications of recovery, because in that year the highest counts ever recorded for common loons in PWS. In addition, July 2000 counts were the third highest of the 11 years since 1972, although these increases were limited to the unoiled portion of the Sound. Loons are a highly mobile species with widely variable population numbers and the pre-spill data were limited, thus this one year of high counts in the unoiled areas was insufficient to indicate that recovery had started.

Population surveys conducted from 1989 - 2005 found increasing winter population trends in common loon densities in oiled areas. The summer counts do not show a consistent positive relationship, however the summer counts of loons are usually low and variable because they are predominately found on their breeding grounds in other areas during the summer. Common loons have an intrinsically low population growth rate and relatively large numbers of carcasses were recovered after the spill, yet post spill winter population counts of common loons have met or exceeded available pre-spill counts for all years measured since the spill, except 1993.

Given the long-term positive changes in winter population information, common loons are considered recovered from effects of the oil spill.

COMMON MURRES

Injury
About 30,000 carcasses of oiled birds were picked up in the first four months following the oil spill, and 74 percent of them were common and thick-billed murres (mostly common murres). Many more murres probably died than actually were recovered. Based on surveys of index breeding colonies at such locations as the Barren Islands, Chiswell Islands, Triplet Islands, Puale Bay, and Ugiaushak Island, the spill area populations may have declined by about 40 percent following the spill. In addition to direct losses of murres, there is evidence that the timing of reproduction was disrupted and productivity decreased. Interpretation of the effects of the spill, however, is complicated by incomplete pre-spill data and by indications that populations at some colonies were in decline before the oil spill.

Recovery Objective
Common murres will have recovered when populations at index colonies have returned to pre-spill levels and when reproductive success (productivity) is sustained within normal bounds. Increasing population trends at index colonies will be an indication that recovery is underway.

Recovery Status
Postspill monitoring at the breeding colonies in the Barren Islands indicated that productive success was within normal bounds by 1993, and it has stayed within these bounds each breeding season since then. During the period 1993-1997, the murres nested progressively earlier by two to five days each year, suggesting that the age and experience of nesting birds were increasing, as might be expected after a mass mortality event. By 1997, numbers of murres at the Barren Island had increased, probably because three- and four-year old nonbreeding sub-adult birds that were hatched there in 1993 and 1994 were returning to their natural nesting colony. Although counts were low in 1996, the counts in 1997 at this index site brought the colony size to pre-spill levels.

The population size coupled with normal reproductive success (productivity), indicate that recovery has been achieved for common murres.

CORMORANTS

Injury
Cormorants are large fish-eating birds that spend much of their time on the water or perched on rocks near the water. Three species of cormorants are typically are found within the oil spill area. Carcasses of 838 cormorants were recovered following the oil spill, including 418 pelagic, 161 red-faced, 38 double-crested, and 221 unidentified cormorants. From this sample, direct oil spill related mortality was estimated at between 2,900 and 8,800 deaths. In 1996, the U.S. Fish and Wildlife Service Alaska Seabird Colony Catalog, however, listed counts of 7,161 pelagic cormorants, 8,967 red-faced cormorants, and 1,558 double-crested cormorants in the oil spill area. These are direct counts at colonies, not overall population estimates, but they suggest that population sizes are small. In this context, it appears that injury to all three cormorant species was significant.

Counts on the outer Kenai Peninsula coast suggested that the direct mortality of cormorants due to oil resulted in fewer birds in this area in 1989 compared to 1986. In addition, there were statistically-significant declines in the estimated numbers of cormorants (all three species combined) in the oiled portion of Prince William Sound based on pre and postspill boat surveys in July 1984-85 compared to 1989-91. It is not known what the counts and trends of cormorants would have been in the absence of the oil spill.

Recovery Objective
Pelagic, red-faced, and double-crested cormorants will have recovered when their populations return to pre-spill levels in oiled areas. An increasing population trend in Prince William Sound will indicate that recovery is underway.

Recovery Status
Marine bird surveys were conducted in ten of the 16 years between 1989-2005. For cormorants, trends for both summer and winter populations were increasing in the oiled area of Prince William Sound. Moreover, population estimates for cormorants in summer 2004 ranged from 9,000 – 11,000 birds, which falls within the range of 10,000 - 30,000 estimated in 1972. **Therefore, although population estimates of cormorants are highly variable throughout their range, the recovery objectives have been met and cormorants are considered to be recovered.**

CUTTHROAT TROUT

Injury
Anadromous streams throughout the spill zone were oiled following the spill in 1989, and oil was sequestered in the intertidal sediments at stream mouths and along shorelines. Subsequently, it was documented that cutthroat trout emigrating within the oiled areas in 1989 -1990 grew more slowly than those in the unoiled areas. When trout leave their freshwater spawning areas they feed primarily in the nearshore environment, thus it is likely cutthroats were exposed to oil in this environment. The difference in growth rates between trout in oiled versus unoiled streams persisted through 1991. It was hypothesized that the slower rate of growth in oiled streams was the result of reduced food supplies or direct exposure to oil, and there was concern that reduced growth rates resulted in reduced survival.

Recovery Objective
Cutthroat trout will have recovered when growth rates within oiled areas are similar to those for unoiled areas, after taking into account geographic differences.

Recovery Status
Limited information exists regarding the current status of cutthroat trout. Recent exposure to lingering oil is unlikely, because most of the bioavailable oil appears to be confined to subsurface intertidal areas, and not dissolved in the water column. Moreover, distribution of cutthroat trout is patchy throughout the Sound, thus access to oil is restricted. However, the Sound is the northern edge of cutthroat trout range and dispersal during marine migration is restricted, thereby increasing their susceptibility to habitat alteration and pollution. Cutthroat trout populations in the Sound are small and geographically isolated from each other: These characteristics suggest that recovery of a population would depend less on mixing with nearby aggregates than on the productivity of the endemic population and the extent to which it was

injured by the spill. Confounding factors such as sport fishing and habitat alteration of spawning streams (e.g., through logging) may also inhibit successful recruitment of young into a population and subsequent increase in numbers.

Finally, growth rate data has not been collected since the early 1990s, thus the recovery objective has not been demonstrated. The recovery status of cutthroat trout remains unknown.

DESIGNATED WILDERNESS AREAS

Injury
The spill deposited oil into the waters and tidelands adjoining areas designated as Wilderness or Wilderness Study Areas by Congress or the Alaska State Legislature. During the intense clean-up seasons of 1989 and 1990, thousands of workers and hundreds of pieces of equipment were at work in the spill zone. This activity was an unprecedented imposition of people, noise, and activity on the area's undeveloped and normally sparsely occupied landscape. Although human activity levels on these wilderness shores have returned to normal, lingering oil still occurs at some locations. The spill-affected areas were: designated wilderness in the Katmai National Park, wilderness study areas in the Chugach National Forest and Kenai Fjords National Park, and Kachemak Bay Wilderness State Park.

Recovery Objective
Designated wilderness areas will have recovered when oil is no longer encountered in them and the public perceives that they are recovered from the spill.

Recovery Status
Six moderately to heavily oiled sites on the Kenai and Katmai coasts were surveyed in 1994, at which time some oil mousse persisted in a remarkably unweathered state on boulder-armored beaches at five sites. These sites were visited again in 1999, and oil was found along park shorelines of the Katmai coast. Surveys carried out in 2001 and 2003 to determine the surface and subsurface distribution of oil in Prince William Sound found lingering oil on shorelines within designated wilderness study areas. Finally, in 2005 the sites surveyed in 1999 were again sampled. Although surface cover of oil had declined, the subsurface oil persisted in amounts similar to those found in 1999. Moreover, the oil at those sites was compositionally similar to samples collected 11-days after the spill.

Lingering oil persists in designated wilderness areas, and quantitative studies of lingering oil outside of Prince William Sound are lacking. However, in many areas absolute amounts of oil are diminishing. Therefore, designated wilderness areas are recovering but have not fully recovered from the oil spill.

DOLLY VARDEN

Injury
Dolly Varden are widely distributed in the spill area. Adults spawn in natal streams and most overwinter in contiguous freshwater lakes. Migration into the marine environment occurs in the summer where the fish spend time feeding in nearshore waters. Many fish were in freshwater when the oil spill occurred but emigrated in and out of the spill area later in the season.

Concentrations of hydrocarbons in the bile of Dolly Varden were some of the highest of any fish sampled in 1989. Like the cutthroat trout, there is evidence from 1989-90 that Dolly Varden, in a small number of oiled index streams in Prince William Sound, grew more slowly than in unoiled streams. It was hypothesized that the slower rate of growth in oiled streams was the result of reduced food supplies or exposure to oil, and there was concern that reduced growth rates would result in reduced survival.

Recovery Objective Dolly Varden will have recovered when growth rates within oiled streams are comparable to those in unoiled streams, after taking into account geographic differences.

Recovery Status

The growth differences between Dolly Varden in oiled and unoiled streams did not persist into the 1990-91 winter, but no growth data have been gathered since 1991. In addition, by 1990 the concentrations of hydrocarbons in bile had dropped substantially and a biochemical marker of oil exposure had a diminished.

In a 1991 restoration study sponsored by the Trustee Council, some tagged Dolly Varden moved considerable distances among streams within Prince William Sound, suggesting that mixing of overwintering stocks takes place during the summer in saltwater. Follow up studies indicate that Dolly Varden are abundant throughout the Sound, and genetically similar among geographically different aggregates. Frequent genetic exchange among groups of fish implies that mixing occurs, and outside populations are available to enhance depleted stocks. Moreover, fishing pressure on Dolly Varden is likely not as intense as that on coastal cutthroat trout. Populations are larger, the fish are more widely spread throughout the Sound and larger numbers can better tolerate harvest. Finally, current exposure to lingering oil is unlikely because most of the bioavailable oil is confined to subsurface intertidal areas and not dissolved in the water column.

Given the available evidence, Dolly Varden are considered to be recovered from effects of the oil spill.

HARBOR SEALS

Injury

Harbor seal numbers were declining in the Gulf of Alaska, including in Prince William Sound, before the oil spill. *Exxon Valdez* oil affected harbor seal habitat, including key haul-out areas and adjacent waters, in Prince William Sound and as far away as Tugidak Island, near Kodiak. Estimated mortality as a direct result of the oil spill was about 300 seals in oiled parts of Prince William Sound. In some parts of the Sound, 80 percent of the seals had oil on them in May 1989 and remained oiled until their molt in August. Some of the haul-out sites were oiled through the pupping season, and many pups became oiled shortly after birth. Based on aerial surveys conducted at trend-count haulout sites in central Prince William Sound before (1988) and after (1989) the oil spill, seals in oiled areas declined by 43 percent, compared to 11 percent in unoiled areas.

Recovery Objective

Harbor seals will have recovered from the effects of the oil spill when their population is stable or increasing.

Recovery Status
Harbor seal populations in the Sound were declining before the oil spill and the decline continued after the spill occurred. Factors contributing to this decline may involve environmental changes that occurred in the 1970s in which the amount and quality of prey resources were diminished. It is possible that the changes in the availability of high quality forage fish such as Pacific herring and capelin altered the ecosystem such that it may now support fewer seals than it did prior to the late 1970s. Other sources of mortality that may be contributing to lower seal numbers could include predation, subsistence hunting, and commercial fishery interactions (e.g., entanglement and drowning in nets).

Satellite tagging studies sponsored by the Trustee Council and genetic studies carried out by the National Marine Fisheries Service indicate that harbor seals in the Sound are largely resident throughout the year and have limited movement and interbreeding with other subpopulations in the northern Gulf of Alaska. This suggests that recovery must come largely through recruitment and survival within resident populations.

Based on annual counts from haulouts concentrated in the south-central region of the Sound, seal numbers stabilized from 1996 – 2005 and likely increased between 2001- 2005. From 1990-2005, seal numbers at sites that were not oiled decreased at a greater rate than oiled sites, indicating no localized effects of the spill. However, the entire spill zone was not surveyed, and trends may have been influenced by movements of seals from oiled to unoiled sites after the spill and a return to more oiled sites in recent years. This hypothesis has not been studied directly. **Collective evidence from the last ten years indicates that harbor seal population numbers are stabilizing or increasing. Therefore, harbor seals are considered recovered from effects of the oil spill.**

HARLEQUIN DUCKS

Injury
Harlequin ducks spend most of their time in intertidal and shallow subtidal habitats where much of the oil was initially stranded. In Prince William Sound, about 150 harlequin duck carcasses were collected immediately after the spill in 1989. From these recovered birds, it was estimated that 1,000 harlequins were killed by the initial oiling event, which represented about 7 percent of the wintering population. In addition to acute effects, harlequin ducks were one of the few species for which chronic injury related to long-term exposure to lingering oil was documented.

Recovery Objective
Harlequin ducks will have recovered when breeding- and nonbreeding-season demographics and biochemical indicators of hydrocarbon exposure in harlequins in oiled areas of Prince William Sound are similar to those in harlequins in unoiled areas.

Recovery Status
Winter populations of harlequin ducks in Prince William Sound have ranged from a high of 19,000 ducks in 1994 to a low of around 11,000 ducks in March of 1990, one year after the spill. The 2000 estimate of wintering harlequin ducks in the Sound was approximately 15,000.

Several post-spill studies were designed to measure the extent and severity of injuries to the Prince William Sound harlequin duck population from the oil spill and assess recovery. Through 1998, oil spill effects were still evident although the extent and magnitude of the injury remained unclear. Supporting studies provided evidence of continuing injury to harlequins through the following mechanisms: 1) invertebrate recovery in upper intertidal and subtidal areas remained incomplete for some species, thereby impacting potential prey base for harlequins; 2) oil persisted in intertidal areas of Prince William Sound where it was identified as a source of contamination of benthic invertebrates; 3) the possibility of external oiling of feathers remained due to lingering surface oil; 4) a biochemical marker of oil exposure (cytochrome P450) was greater in tissues of harlequin ducks captured in oiled areas than in reference areas and 5) overwinter female survival was lower in oiled than reference areas.

More recent studies indicate improving conditions. From 1997 – 2005, age composition and population trends were compared in harlequin ducks between oiled and unoiled areas of the Sound. No difference in population trends was observed between areas. Although populations in the oiled area were no longer declining as they were in the mid 1990s, a positive trend was not observed. Overall, more males than females occurred Sound-wide which is consistent with other Pacific populations of harlequin ducks. The ratio of immature to adult males was similar between areas, thus indicating similar recruitment into both populations. However, there remains a disproportionately lower number of female ducks in the oiled areas. From 2000 – 2002, measurements of cytochrome P450 activity and female survival rates were converging between oiled and unoiled areas. However, in 2005 and 2008 the P450 biomarker was elevated in ducks from the oiled areas. Finally, lingering oil still remains in habitats used by harlequins, thereby maintaining the possibility of chronic effects related to continued exposure.

Evaluation of population trends, survival measures, and indicators of exposure through 2008 indicates a positive relationship among these parameters within harlequin duck populations in the Sound. The evidence suggests that harlequin ducks are recovering, but have not fully recovered from the effects of the oil spill.

INTERTIDAL COMMUNITIES

Injury

Over 1,400 miles of coastline were oiled by the spill in Prince William Sound, on the Kenai and Alaska peninsulas, and in the Kodiak Archipelago. Heavy oiling affected approximately 220 miles of this shoreline. It is estimated that 40-45 percent of the 11 million gallons of crude oil spill by the Exxon Valdez washed ashore in the intertidal zone. For months after the spill in 1989, and again in 1990 and 1991, both oil and intensive clean-up activities had significant impacts on the flora and fauna of this environment.

Initial impacts to the intertidal zone occurred at all tidal levels and in all types of habitats throughout the oil spill area. Direct assessment of the spill effects included sediment toxicity testing, documenting abundance and distribution of intertidal organisms and sampling ecological parameters of community structure. Dominant species of algae and invertebrates directly affected by the spill included common rockweed, speckled limpet, several barnacle species, blue mussels, periwinkles, and oligochaete worms. At lower elevations on gravel and mixed sand/gravel beaches, the abundance of sediment organisms and densities of clams declined. Large numbers of dead and moribund clams were documented on treated beaches, but these effects were likely due to a combination of oil toxicity and hot water washing. Intertidal fish were also affected. In a study conducted in different habitats, density and biomass of fish at oiled sites showed declines relative to reference sites in 1990.

Recovery Objective

Intertidal communities will have recovered when such important species as *Fucus* (marine algae/seaweed) have been reestablished at sheltered rocky sites, clams and mussels at soft or mixed sediment beaches are not contaminated by residual oil, the differences in community composition and organism abundance on oiled and unoiled shorelines are no longer apparent after taking into account geographic differences, and the intertidal and nearshore habitats provide adequate, uncontaminated food supplies for predators and subsistence users.

Recovery Status

By 1991, in the lower and middle intertidal zones, algal coverage and invertebrate abundances on oiled rocky shores had returned to conditions similar to those observed in unoiled areas. However, large fluctuations in the algal coverage in the oiled areas caused a subsequent alteration in community structure. The *Fucus* canopy was initially eliminated in most of the areas that underwent extensive cleaning, thereby removing the protection provided by this alga to intertidal organisms from predation, desiccation and abrasion. This early eradication of *Fucus* led to instability of this alga's subsequent populations because the single-aged stands present after recolonization of the habitat were susceptible to large synchronous die-offs. Until a broader distribution of mixed-aged stands is established, this cycle may continue for many generations. Meanwhile, full recovery of *Fucus* is crucial for the recovery of intertidal communities at oiled sites, because many intertidal organisms depend on the shelter this seaweed provides.

As of 1997, *Fucus* had not yet fully recovered in the upper intertidal zone on shores oriented towards direct sunlight, but in many locations, recovery of intertidal communities had been substantial. In other habitat types, such as estuaries and cobble beaches, many species did not show signs of recovery when they were last surveyed in 1991. Studies on the effects of clean-up activities on oiled and washed beaches showed some invertebrates, like molluscs and annelid worms were still much less abundant than on comparable unoiled beaches through 1997. It is undetermined how much recovery has occurred in these locations since 1997, because further work has not been conducted.

Lingering oil is still present in some intertidal areas within the spill zone. Recent studies indicate that at beaches with pockets of buried lingering oil, high amphipod mortality is associated with elevated hydrocarbon concentrations. Moreover, the recovery objective states that the intertidal zone must provide uncontaminated food to top predators, including human subsistence users. As recently as 2005, some bird species which rely exclusively on the intertidal zone (harlequin ducks, Barrow's goldeneye and black oystercatchers) were still being exposed to hydrocarbons. Although the route of oil exposure has not been established, it is possible they are consuming contaminated prey during feeding.

Reestablishment of functioning intertidal communities is progressing, and they are classified as recovering. However, the slow recovery of some soft-sediment intertidal invertebrates, the presence of lingering, bioavailable oil, the continuing oil exposure of obligate intertidal foragers that are known to eat clams, and the lack of recent data characterizing the intertidal community indicate that this resource has not fully recovered from the effects of the oil spill.

KILLER WHALES

Injury

More than 160 killer whales in eight resident (fish eating) pods regularly use Prince William Sound/Kenai Fjords as part of their ranges. Transient (marine mammal eating) groups are observed in the Sound less frequently, but some (the AT1 population) use the Sound year-round. After the spill, the loss of individual whales from the resident AB pod was of particular concern. At the time of the spill, this group numbered 36 animals, and from 1989 - 1990, fourteen whales disappeared. During that time no young were recruited into the population. Members of the transient AT1 population were also observed in the area of the spill and adjacent to the tanker as it was leaking oil. Two stranded whales were found in 1990, but their cause of death was not determined.

The original link between the AB pod losses and the oil spill was largely circumstantial. No carcasses of any resident whales were discovered. However, whales were observed surfacing in Exxon Valdez oil slicks following the spill in 1989 and nearly all of the deaths occurred at the time of the spill or the following winter. It is likely that petroleum or petroleum vapors were inhaled by whales, and it is also possible that they ate contaminated fish. The mortality rate for the AB pod was 19 percent in 1989 and 21 percent in 1990, compared to an expected natural mortality rate of 2.2 percent or less.

The AT1 population also suffered losses subsequent to the spill. The AT1 population centers its range around the Sound and Kenai Fjords. From 1984 – 1989, their numbers were stable at 22 regularly observed individuals, but in a retrospective analysis it was determined that nine whales disappeared shortly after the spill. Because transients may occasionally leave their groups and swim with other transient whales, it could not be immediately determined if these whales were dead. However, in the subsequent 15 years these individuals were not seen by researchers with any other transient groups and they had not reappeared with their original group. Thus, they were considered deceased. It was hypothesized that these whales died from inhaling toxic oil vapors or as a result of eating oiled harbor seals.

Initially it was difficult to confirm deaths of individual whales from the AT1 population. However, since 1990, 14 whales have gone missing from the AT1 group and are now almost certainly deceased (five of the carcasses were found on beaches). During that same period there has been no recruitment of calves into this group of transients. The timing and magnitude of missing individuals directly following the spill and the fact that the ATI pod is a year-round resident of the Sound suggests that oil may have caused a decline immediately after the spill.

Recovery Objective

The recovery objective for killer whales is a return to a pre-spill number of 36 for the AB pod and a stable population trend in AT1 pod.

Recovery Status

From 1990–1995 seven calves were born within the AB pod: however, additional mortalities occurred and by 2005, the number of whales was only 27. Killer whales are long-lived and slow to reproduce. Female killer whales give birth about every five years, and are likely to produce only four to six calves throughout their life. Moreover, a disproportionate number of females were lost at the time of the spill, and population modeling has demonstrated that the spill impacted the AB pod primarily through the loss of young and reproductive females. Unexpected mortalities in the years since the spill have also impacted this group. These factors indicate that the recovery rate of this population after a large loss of individuals will be slow.

Transient killer whales, such as the AT1 pod, largely prey on marine mammals, especially harbor seals. From data collected at haul-outs in the south-central region of the Sound, it appears that harbor seals numbers may have increased over the past five years. It is unclear how the population dynamics of harbor seals influence transient whale populations, but changes in the availability of such an important prey species could impact survival of individuals and reproductive success within groups. Research sponsored by the Trustee Council on contaminants in killer whales in the Sound indicates that individuals of the AT1 group are carrying elevated levels of PCBs, DDT, and DDT metabolites in their blubber. Although the presence of these contaminants is not related to the oil spill, the high concentrations found in these transients are comparable to levels that cause reproductive problems in other marine mammals. Accordingly, it is likely that the population dynamics of this group are being influenced by factors other than residual oil which may further their ability to rebound from the initial injury from the spill.

Killer whales have not met their recovery objective; however numbers of whales in the AB pod have increased from 22 to 29. Therefore, they are considered recovering from the effects of the spill.

KITTLITZ'S MURRELETS

Injury

The Kittlitz's murrelet is found only in Alaska and portions of the Russian Far East. A large percentage of the world population, which may number only a few tens of thousands, breed in Prince William Sound. The Kenai Peninsula coast and Kachemak Bay are also important concentration areas for this species.

Seventy-two Kittlitz's murrelets were positively identified among the bird carcasses recovered after the oil spill. Nearly 450 more Brachyramphus murrelets were not identified to the species level, and it is reasonable to assume that some of these were Kittlitz's. In addition, many more murrelets probably were killed by the oil than were actually recovered. Estimates of the total number of Kittlitz's murrelets that died as a result of the spill vary from 255 – 2,000; it has been suggested that this represents 5 – 10 percent of the world's population.

Recovery Objective

Kittlitz's Murrelets will have recovered when their population is stable. Stable or increasing productivity within normal bounds will be an indication that recovery is underway.

Recovery Status

Few studies have been conducted on Kittlitz's murrelets, however they are known to nest in areas of glacial outcroppings, and they are thought to reside within the Sound from May until September/October. Kittlitz's murrelets have an intrinsically low population growth rate, thus recovery from an acute loss is likely to be slow.

The Kittlitz's murrelet is a candidate species for listing as threatened or endangered under the federal Endangered Species Act. They declined 99 percent from 1972 to 2004 and 88 percent from 1989 – 2004. While this decline likely started prior to the spill, the rate of decline was 18 percent per year from 1972, but beginning in 1989 that rate increased to 31 percent. The recovery status of Kittlitz's is complicated because confounding factors influence their current population growth. The decline may be attributable in part to a decline in a primary food source; high-lipid forage fish, like sand lance and Pacific herring. However, other factors with no potential connection to the oil spill-e.g., habitat loss, likely play a significant role as well. For example, most of the tidewater glaciers in the Sound associated with these birds are receding, and this is apparently causing a concurrent shift in murrelet distribution. **Because of the uncertainties surrounding the original extent of injury and the current limited availability of life history data, the Kittlitz's murrelets remain in the unknown category.**

MARBLED MURRELET

Injury

Marbled murrelets are found throughout the northern Gulf of Alaska and are known to concentrate in Prince William Sound. Carcasses of nearly 1,100 Brachyramphus murrelets were found after the spill, and about 90 percent of the murrelets that could be identified to the species level were marbled murrelets. Since they are a small bird and not easily seen, many more murrelets probably were killed as a result of the oil than were found. Estimates vary but between 2,900 and 14,800 individuals were killed by the initial oiling and this represented 6 – 12 percent of the marbled murrelets in the spill area. In addition to direct mortality, foraging activity and behavior was likely disrupted during the clean-up activities.

Recovery Objective

Marbled murrelets will have recovered when their population has recovered to a level had the spill not occurred. Sustained or increasing productivity within normal bounds will be an indication that recovery is underway.

Recovery Status

Marbled murrelets were declining in the Sound before the oil spill, and the decline has continued since the spill. It is listed as a threatened species in Washington, Oregon, California and British Columbia. Marbled murrelets have low intrinsic productivity and a slow population growth rate. Therefore, recovery from an acute loss will likely take many years.

Summer populations in the Sound declined from an estimated 304,000 birds in 1972 to 97,000 shortly after the spill. Population trends from 1989 – 2005 do not indicate increasing numbers of marbled murrelets. Comparing summer population trend data of marbled murrelets between oiled and unoiled areas is difficult because of widespread nesting distributions and overlapping foraging ranges. Moreover, declines in marbled murrelet breeding populations are occurring in both oiled and unoiled areas. Similar trends throughout the Sound suggest that factors, other than or in addition to the oil spill are influencing murrelet populations. Marbled murrelets rely on forage fish such as Pacific herring and sand lance, which are declining in the spill area for various reasons including a potential link to the oil spill. Although a correlation between the availability of forage fish and the production of young murrelets appears to exist, there is conflicting evidence that links declines in prey resources with the oil spill. However, other factors with no potential link to the spill, such as climate change, decreases in habitat availability and mortalities from the gill net fisheries are probably influencing marbled murrelet population dynamics. Although lingering oil exists in the Sound, the dietary preference and foraging areas of marbled murrelets do not provide much opportunity for current exposure.

Marbled murrelets do not meet their specific recovery objective of increasing or stable populations. Moreover, their decline could be attributable in part to a decline in a primary food source; high-lipid forage fish, like sand lance and Pacific herring. Based on available data, we cannot make a direct link among the decline in forage fish, the effects of the spill and the decline in marbled murrelets. Therefore, the recovery status for marbled murrelets is unknown.

MUSSELS

Injury
Mussels are a keystone species in the nearshore environment throughout the spill area and are locally important for subsistence users. They provide prey for harlequin ducks, black oystercatchers, juvenile sea otters, river otters and many other species. Mussel beds are also important components of intertidal habitats because they provide physical stability and habitat for other organisms in the intertidal zone. Although mussels were coated with oil from the *Exxon Valdez*, dense mussel beds were purposely not disturbed during clean-up operations so the stability and habitat they provided would be preserved. However, some unconsolidated groups of mussels were subjected to hot water high pressure washing.

In 1989, after the spill, concentrations of oil in mussel tissue from the oiled area increased rapidly. These concentrations were typically far higher than in mussels from nonoiled areas (or in mussels sampled from 1977-1979). The chemical composition of this oil was consistent with *Exxon Valdez* oil. Long-term mussel contamination occurred where substantial amounts of oil was trapped in sediment; primarily within coarse-textured habitats, including heavily oiled beaches exposed to considerable wave and storm energy (e.g., Sleepy Bay). In 1991, high concentrations of relatively unweathered oil were found in the mussels and in underlying byssal mats and sediments in certain dense mussel beds. No differences in abundance or biomass were documented in sheltered rocky and estuarine habitats. However, in coarse-textured habitats along the Kenai Peninsula, mussel populations were still affected.

Recovery Objective
Mussels will have recovered when population ands productivity at oiled sites are comparable to populations and productivity at unoiled sites, when chemical markers no longer indicate oil exposure, and when mussels can provide adequate, uncontaminated food supplies for predators and subsistence users.

Recovery Status
The primary route by which mussels accumulate oil is through ingestion of petroleum hydrocarbons in the water. Much of the lingering oil in the Sound and the Gulf of Alaska is sequestered in the subsurface sediments. Mussels are found both as epibiota, attached to the surface substrates, and also partially embedded in coarse sediment, where they could come into close contact with oiled sediments. It is possible that mussels could filter particulate and dissolved hydrocarbons from the water if the oil is re-suspended during storm surges, wave action or when underlying sediments are disturbed by predators. The current distribution of oil within a mussel bed is determined by water flow, amount of oil present, sediment grain size, and disturbance history.

After the spill, hydrocarbons accumulated in mussels for about a decade at sites where oil was retained in sediments. Remaining oil was biologically available for many years after the spill, but the frequency of occurrence and average hydrocarbon concentrations in mussel tissue has declined with time. In most instances concentrations of oil in mussels from the most heavily oiled beds in Prince William Sound were largely indistinguishable from background by 1999. However, concentrations in sediment underlying the mussel beds remained elevated.

Recent data indicate that hydrocarbon concentrations in mussels are declining, even in armored beaches where elimination has been slow, and at many sites concentrations are not different from background. While a decrease in tissue concentration addresses part of the recovery objective, in order to be fully recovered mussels must provide uncontaminated food to top predators, including human subsistence users. As recently as 2008, some bird species which rely exclusively on the intertidal zone (harlequin ducks, Barrow's goldeneye and black oystercatchers) were still being exposed to hydrocarbons. The route of oil exposure has not been established for these birds, however, it is possible that they are consuming contaminated prey or foraging in contaminated sediment during feeding. For many of these species mussels are a known prey item, and they could be foraging in contaminated sediments underlying mussel beds. **Because it cannot be verified that predators are not being exposed to oil while foraging in mussel beds, mussels are considered to be recovering from the effects of the oil spill.**

PACIFIC HERRING

Injury

Pacific herring are an ecologically and commercially important species in the PWS ecosystem. They are central to the marine food web; providing food to marine mammals, birds, invertebrates and other fish. Herring are also commercially fished for food, bait, sac-roe and spawn on kelp.

Pacific herring spawned in intertidal and subtidal habitats in Prince William Sound shortly after the oil spill. All age classes and a significant portion of spawning habitats and staging areas in the Sound were contaminated by oil. Juvenile and adult herring typically come to surface at night to feed and would have had increased exposure probability at this time. Lesions and elevated hydrocarbon levels were documented in some adult Pacific herring from the oiled areas. Laboratory studies showed abnormalities and possible depressed immune functions in Pacific herring exposed to oil. Significant adult mortality was not observed in 1989, but this would not be unexpected given the heavy predation or scavenging by different groups of predators. Egg mortalities and larval deformities were also documented in the 1989 year class, but population level effects of the spill were never clearly established.

Prior to the spill, herring populations in the Sound were increasing as documented by record harvests in the late 1980s. However, four years after the spill a dramatic collapse of the fishery occurred, and the herring population has never rebounded. Herring populations are dominated by occasional, very strong year classes that are recruited into the overall population. The 1988 pre-spill year-class of Pacific herring was large in Prince William Sound, and as a result, the estimated peak biomass of spawning adults in 1992 was high. Despite the expectation that this large spawning event would lead to high numbers of fish, the population exhibited a density-dependent reduction in size of individuals, and in 1993 there was an unprecedented crash of the adult herring population in PWS. The overall 1993 harvest was about 14 percent of the 1992 harvest, and the 1989 year class was one of the smallest cohorts ever to return as spawning adults.

Recovery Objective

The population of PWS Pacific herring will be considered recovered when the spawning biomass has been above the current regulatory fishery threshold of 43,000 tons for 6 to 8 years; two strong recruitments (> 220 million) of age-3 fish have occurred during those 6 to 8 years, and spawning occurs in at least three geographic regions of the Sound.

Recovery Status

The herring fishery in the Sound has been closed for 15 of the 20 years since the spill. The population began increasing again in 1997 and the fishery was opened briefly in 1997 and 1998. However, the population increase stalled in 1999, and recent research suggests that the opening of the fishery in 1997 and 1998 stressed an already weakened population and contributed to the 1999 decline. The fishery has been closed since then and no trend suggesting healthy recovery has occurred.

One of the primary factors currently limiting recovery of herring in the Sound seems to be disease. Two pathogens, a virus and a fungal infection are prevalent in herring populations among several age classes. Conditions which made herring susceptible to these two diseases (viral hemorrhagic septicemia and Icthyophonus hoferi infection) are unknown, but it appears they have been impacting herring for over a decade. These diseases do not usually distress fish populations for such a long duration, and this cycle seems to be unique to the herring of Prince William Sound.

Lingering oil exists in the Sound, however there does not appear to be much overlap between current herring spawning areas and sites known to harbor residual oil. In 2006, some herring spawn was observed in areas of the Sound that were oiled however, the spatial extent was limited, and this was the first year in decades that it has been reported. Therefore, it is not likely that lingering oil is directly affecting spawning adults, eggs or larvae.

Low genetic diversity does not appear to be a limitation within herring populations. It was suggested that historic overfishing coupled with the population crash of 1993 could have resulted in a population with low genetic diversity. Similar genetic structure could limit a population's ability to tolerate disease or recover from acute losses, but the genetic diversity of Prince William Sound herring is no different from other northwest populations.

Multigenerational toxicity and effects from original contact with oil does not seem plausible, however this hypothesis has not been directly investigated.

Other factors may have contributed to the crash of 1993. Some evidence implies that zooplankton production in the 1990s was less than in the 1980s, thereby causing food to be limited at the time of a peaking population. This hypothesis is offered some support by the fact that the average size-at-age of herring had been decreasing since the mid-1980s as population numbers were rising. Poor nutrition may also increase susceptibility of herring to disease.

Predation also plays a role in herring population dynamics, as they are a primary forage fish within the Prince William Sound ecosystem. It is plausible that the small herring population is fighting an on-going disease problem and is further being kept in check by predators such as whales, seals, sea lions and seabirds.

Despite the numerous studies directed at understanding the effects of oil on herring, the causes constraining population recovery are not well understood. A combination of factors, including disease, predation and poor recruitment appear to contribute to the continued suppression of herring populations in the Sound. In summary, PWS Pacific herring have not met their recovery objective. No strongly successful year class has been recruited into the population and health indices suggest that herring in the Sound are not fit. Therefore, the Pacific herring are classified as not recovering.

PIGEON GUILLEMOTS

Injury

Although pigeon guillemots are widely distributed in the North Pacific region, they do not occur anywhere in large concentrations. An estimated 2,000 - 6,000 guillemots, representing 10-15 percent of the spill area population, died from acute oiling. Additionally, an increase in nest predation of pigeon guillemot chicks and incubating adult birds occurred in the Sound after the spill. Researchers speculated that immediately after the spill, predators such as river otters and minks preyed more heavily on nesting guillemots due to heavy oiling and subsequent reduction of their customary shellfish prey.

Recovery Objective

Pigeon guillemots will have recovered when their population is stable. Sustained or increasing productivity within normal bounds will be an indication that recovery is underway.

Recovery Status

Pigeon guillemot populations were likely declining prior to the spill and this decline has continued through 2008. The causes of the decline are unclear and the extent to which the spill has been a factor has not been determined. From 1989 to 1991, pigeon guillemot abundance decreased more in oiled areas than in unoiled areas, and this accelerated decrease persisted in most years through 2001. Summer surveys along both oiled and unoiled shorelines of the Sound have indicated that numbers of guillemots continued to decline through 2005. March surveys reveal no significant trends in abundance although the data appear to suggest a decline at this time of year as well.

As of 1999, adult pigeon guillemots in the oiled areas were still being exposed to oil as indicated by elevation of a biochemical marker of exposure, cytochrome P450. No differences were found between P450 activity in chicks from oiled and unoiled sites. The difference in P450 activity between adults and chicks is probably due to the fact that pigeon guillemot chicks are fed primarily fish, while adults eat a combination of fish and invertebrates. Invertebrates are more likely to sequester petroleum compounds, whereas fish metabolize them. Data collected in 2004 indicated that there was no difference in P450 activity in adult pigeon guillemots collected in oiled and unoiled parts of the Sound.

Lingering oil occurs in habitats used by pigeon guillemots. They feed on fish and invertebrates by diving and probing the substrate with their bills. Because their diet includes benthic organisms living in the intertidal zone, they could encounter subsurface oil while foraging.

However, guillemots do not use the intertidal zone exclusively and can travel several miles offshore to feed. Thus, their exposure to lingering oil is likely intermittent.

Reduction in forage fish, specifically herring and sand lance, has been implicated in declines of pigeon guillemots. The extent to which the oil spill resulted in the depletion of these species could indirectly injure guillemots and other seabirds by removing the food resources on which they depend. Other factors, such as predation and interactions with commercial fisheries, might be contributing to the negative population trend; however comprehensive studies including these variables have not been conducted.

Pigeon guillemot populations are not recovering in the spill area. In fact, populations have been steadily declining throughout the Sound since the spill. The reduction of Pacific herring as a prey species, coupled with the potential for direct exposure of pigeon guillemots to lingering oil in localized intertidal areas, supports a conclusion that pigeon guillemots remain in the category of not recovering from the effects of the spill.

PINK SALMON

Injury

Up to 75 percent of wild pink salmon in Prince William Sound spawn in the intertidal portions of streams. Eggs deposited in gravel and developing embryos were chronically exposed to hydrocarbon contamination from the water column and from leaching oil deposits on adjacent beaches. When juvenile pink salmon migrate to saltwater, they spend several weeks foraging for food in nearshore habitats. Thus, juvenile salmon entering seawater from both wild and hatchery sources were likely exposed to oil as they swam through contaminated waters and fed along oiled beaches. Two primary types of injury impacted early life stages of pink salmon: 1) growth rates in both wild and hatchery-reared juvenile pink salmon from oiled parts of the Sound were reduced; and 2) increased embryo mortality was documented in oiled versus unoiled streams.

Recovery Objective

Pink salmon will have recovered when population indicators, such as juvenile growth and survival, are within normal bounds and when ongoing oil exposure, which may cause injury to pink salmon embryos (eggs), is negligible.

Recovery Status

In the years preceding the spill, returns of wild pink salmon in Prince William Sound varied from a maximum of 23.5 million fish in 1984 to a minimum of 2.1 million in 1988. Many factors, such as the timing of spring plankton blooms and changes in water circulation patterns throughout the Gulf of Alaska are likely to have a great influence on year-to-year returns in both wild and hatchery stocks of pink salmon. Since the spill, returns of wild pinks have varied from a high of about 12.7 million fish in 1990 to a low of about 1.9 million in 1992. In 2001 the return of wild stock fish was estimated to be 6.7 million fish.

The decade preceding the oil spill was a time of peak productivity for pink salmon in the Sound. In 1991 and 1992, it appears that wild adult pink salmon returns to the Sound's Southwest District were reduced by 11 percent; however wild salmon returns are naturally highly variable. Furthermore, the methods used to estimate this decrease could not be used to produce reliable injury estimates across multiple generations of salmon. An analysis of escapement data from 1968-2001 did not show any differences in annual escapements between oiled and unoiled parts of the Sound. Therefore, population-level effects from the spill did not impact wild pink salmon or were short-lived.

Sound-wide population levels appear to be within normal bounds. In addition, reduced juvenile growth rates in Prince William Sound occurred only in the 1989 season. Since then, juvenile growth rates have been within normal bounds.

Higher embryo mortality persisted in oiled streams when compared to unoiled streams through 1993: These differences were not detected from 1994 - 1996, but higher embryo mortality was again reported in 1997. It could not be determined if the reemergence of elevated embryo deaths was due to the effects of lingering oil (perhaps newly exposed by storm-related disturbance of adjacent beaches), or due to other natural factors (e.g., differences in the physical environment). Although patches of lingering oil still persist in or near intertidal spawning habitats in a few of the streams used by pink salmon in southwestern Prince William Sound, the amounts were considered negligible based on 1999 and 2001 studies. In 1999, dissolved oil was measured in six pink salmon streams that had been oiled in 1989. Only one of the six streams had detectable concentrations of oil, and they were about a thousand times lower than concentrations reported as toxic to developing pink salmon embryos. **Based on these results, continuing exposure of pink salmon embryos to lingering oil is negligible and unlikely to limit pink salmon populations. Given the fact that pink salmon population levels and indicators such as juvenile growth and survival were within normal bounds, pink salmon were considered recovered from the effects of the oil spill in 1999.**

River Otters

Injury

River otters have a low population density in Prince William Sound. Twelve river otter carcasses were found following the spill, but the actual total mortality is not known. Studies conducted during 1989-91 identified several differences between river otters in oiled and unoiled areas in the Sound, including biochemical alterations, reduced body size, and increased home-range size. The lack of comparable pre-spill information precluded any effort to determine if these differences were the result of the oil spill.

Recovery Objective

The river otter will have recovered when biochemical indicators of hydrocarbon exposure or other stresses and indices of habitat use are similar between oiled and unoiled areas of Prince William Sound, after taking into account any geographic differences.

Recovery Status

Although some of the differences (e.g., values of blood characteristics) between river otters in oiled and unoiled areas in Prince William Sound were apparent through 1996, they did not persist in 1997 and 1998. **In 1999, the Trustee Council considered river otters to be recovered, because the recovery objectives had been met and indications of possible lingering injury from the oil spill were not present.**

ROCKFISH

Injury

Dead rockfish were observed throughout the Sound immediately following the spill, but an absolute count was never documented. Necropsies of five fish indicated that oil ingestion was the cause of death. Additionally, hydrocarbon concentrations in dead fish from oiled areas were higher than those from unoiled areas. Closures to salmon fisheries apparently caused increasing fishing pressure on rockfish, which may have adversely affected local populations.

Recovery Objective

Due to the continuing lack of data on rockfish, no recovery objective can be identified.

Recovery Status

From 1989 – 1991, higher petroleum hydrocarbon concentrations were measured in rockfish from oiled areas when compared to unoiled areas. Interpretation of these data is limited, however, because oil accumulation differs by species and by age of the fish, and these variables were not fixed across sites. Other Council-funded studies have been conducted on rockfish since the spill, including 1) an examination of larval growth of fish, (including rockfish) in 1989; 2) a genetics investigation designed to identify species of rockfish larvae and young in the Gulf of Alaska and 3) a microscopic examination of fish tissues to identify lesions associated with oil exposure. These studies were inconclusive as none of them directly linked exposure of *Exxon Valdez* oil to any of the endpoints that were measured.

It is unlikely that rockfish are currently being exposed to lingering oil because known pockets of lingering oil rarely occur in their preferred habitat. Documented lingering bioavailable oil is in the subsurface sediments of the intertidal zone, and rockfish mostly occur in differing habitats of subtidal areas and in pelagic environments. From 1999 – 2000, no differences were measured in physiological responses to oil in rockfish from oiled and unoiled areas.

Since the spill, few studies have provided information about rockfish abundance, species composition and the impacts of commercial fisheries. Although it is unlikely that most species and life-stages of rockfish are currently being exposed to lingering oil, the original extent of injury was not documented. **Therefore, the current understanding of the long-term effects of the original spill can not be determined. The recovery status of rockfish remains unknown.**

SEA OTTERS

Injury

Sea otters were originally found throughout the north Pacific including Japan, Russia, the United States and Canada. By the late 1800s, they had been eliminated from most of their range due to over-harvest by Russian and American fur traders. Sea otters came under international protection in the early 1900s and since then, their numbers have rebounded. Today, sea otters can only be harvested for subsistence purposes. Surveys of sea otters in the 1970s and 1980s indicated a healthy and expanding population in most of Alaska, including Prince William Sound.

Hundreds of otters became coated with oil in the days following the spill, and 871 carcasses were collected throughout the spill area. Estimates of the total number of sea otters lost to acute mortality vary, but range as high as 40 percent (2,650) of the approximately 6,500 sea otters inhabiting the western areas of the Sound. In 1990 and 1991, higher than expected proportions of prime-age adult sea otters were found dead in western Prince William Sound. Higher mortality of recently weaned juveniles in oiled areas was documented through 1993. Continuing studies of mortality rates, based largely on sea otter carcass recoveries, suggest that relatively poor survival of otters in the oiled area has persisted for well over a decade.

Recovery Objective

Sea otters will have recovered when the population in all oiled areas returns to conditions that would have existed had the spill not happened, and when biochemical indicators of hydrocarbon exposure in otters in the oiled areas are similar to those in otters in unoiled areas. An increasing population trend and normal reproduction and age structure in western Prince William Sound will indicate that recovery is underway.

Recovery Status

No apparent population growth occurred for Prince William Sound sea otters through 1991. After 1993, the population in the western Sound began increasing at a rate approximately one-half of the pre-spill rate of increase. From 1993 -2000, the number of otters increased by 600 animals which represents an annual growth rate of 4 percent. However, in areas that were heavily oiled, such as northern Knight Island, sea otter populations have remained well below pre-spill numbers, and population trends continued to decline through 2005. Moreover, the demographics within this group apparently are not stable as many of the females are below reproductive age and young, non-territorial males have moved into and out of the population.

The lack of recovery may reflect the extended time required for population growth for a long-lived mammal with a low reproductive rate, but likely reflects the effects of chronic exposure to hydrocarbons, or a combination of both factors. Food limitation does not appear to be a factor limiting recovery in the Knight Island group, because food resources are at least as plentiful there as they are at unoiled Montague Island. Productivity is also similar between oiled and unoiled sites. Exposure of sea otters to lingering oil is plausible because their foraging sites and prey species occur in habitats harboring oil. Additionally, biochemical responses (cytochrome P450) of oil exposure were elevated in animals from oiled sites through 2002. By 2004 – 2005, the response of this biomarker was similar in animals from oiled and unoiled areas. However, additional years of data will need to be gathered to determine if the similarity is true convergence, and the apparent diminishing exposure to oil is a long-term trend.

Sea otter recovery is underway for much of western Prince William Sound, and sea otters are generally increasing in much of the spill area. However, the data from otters in heavily oiled Knight Island reflect a population that is not rebounding. Factors affecting this population could include residual or continuing oil effects, predation, subsistence use or a combination of multiple causes. **Therefore, sea otters continue to be in the recovering category.**

SEDIMENTS

Injury

The Exxon Valdez spilled approximately 11 million gallons of crude oil into Prince William Sound, and much of this oil washed up on shores and was deposited in intertidal and subtidal zones of the spill area. Intertidal shorelines captured approximately 40 – 45 percent of the oil, and up to 13 percent of the oil settled in subtidal habitats. Using a variety of methods, manual removal eliminated some of the oil from the intertidal zone early in the response phase, and within a few months of the spill, 89 percent of the moderately to heavily oiled beaches had been treated. Clean-up activities also occurred in 1990 and 1991. According to Shoreline Clean-up Assessment Team (SCAT) surveys, by 1992, approximately 10 km of the original estimated 583 km beaches with surface oiling remained uncleaned. The SCAT surveys were focused on documenting surface oiling as a way to direct clean-up activities. Therefore, subsurface and subtidal oil was not as closely monitored.

Recovery Objective

Sediments will have recovered when there are no longer significant residues of Exxon Valdez oil on shorelines (both intertidal and subtidal) in the oil spill area. Declining oil residues and diminishing toxicity are indications that recovery is underway.

Recovery Status

Approximately 10 acres of Exxon Valdez oil remains in surface sediments of Prince William Sound, primarily in the form of highly weathered, asphalt-like or tar deposits. In 2003, it was estimated that 20 acres of unweathered, lingering oil may still be present in subsurface, intertidal areas of the Sound, which could represent up to 100 tons of remaining oil. Most of this oil is found in protected, unexposed bays and beaches. Subsurface oil was not subjected to the original clean-up activities, and because this oil is trapped beneath a matrix of cobbles, gravel and finer sediments, it is not easily exposed to natural weathering processes.

The most recent studies documenting residual oil occurred on those beaches that were considered heavily or moderately oiled in 1989: Beaches reported as lightly oiled were not surveyed. Moreover, beaches outside of the Sound were not included, so the amount and extent of residual oil in the entire spill zone is not known, but one estimate suggests as much as 200 tons of oil may still exist. Several studies have evaluated the extent of lingering oil on armored oiled beaches along the outer Kenai Peninsula coast, the Alaska Peninsula, and Kodiak Archipelago: These studies looked at the same sites repeatedly at intervals from 1992 - 2005. By 1995, little visible oiling was observed in the study area on Kodiak. Overall, by 1995, hydrocarbon concentrations in sediments at the Gulf of Alaska sites were generally lower than for sites in Prince William Sound, but at some locations substantial concentrations persisted. Through 2005, surface oil was not frequently observed in these areas, and subsurface oil was present as mostly unweathered mousse.

In 1989, chemical analysis of oil in subtidal sediments was conducted at a small number of index sites in Prince William Sound. In the subtidal areas, petroleum hydrocarbon concentrations were highest at depths of 1 - 60 feet (below mean low water) and diminished out to depths of 300 feet. It is likely that oil in subtidal sediments have decreased substantially since the spill. In 2001, several sites that were sampled after the spill were re-visited, and no oil was found in the subtidal sediment from these locations.

Seventeen years after the spill, lingering oil has persisted in the intertidal zones of Prince William Sound and on northwest shorelines of the spill area. The presence of subsurface oil continues to compromise wilderness and recreational values, expose and potentially harm living organisms, and offend visitors and residents, especially those who engage in subsistence activities along still-oiled shorelines. Although much of the oil has diminished over time, pockets of unweathered oil exist, and natural degradation of this oil is very slow. Moreover, some obligate intertidal foraging bird species are still being exposed to oil. **Therefore, sediments are considered to be recovering, but not yet recovered from the effects of the spill.**

SOCKEYE SALMON

Injury

Commercial salmon fishing was closed in Prince William Sound and in portions of Cook Inlet and near Kodiak in 1989 to avoid the possibility of contaminated salmon being sold at market. As a result, there were higher-than-desirable numbers (i.e., "overescapement") of spawning sockeye salmon entering the Kenai River and Red and Akalura lakes on Kodiak Island. Initially, these high escapements produced an overabundance of juvenile sockeye that overgrazed the zooplankton, and altered planktonic food webs in the nursery lakes. As a result, growth rates were reduced during the freshwater stage of the salmon's life cycle, which led to a decline in returns of spawning adults. The net result was an initial loss of sockeye production.

Recovery Objective

Sockeye salmon in the Kenai River system and Red and Akalura lakes will have recovered when adult returns-per-spawner are within normal bounds.

Recovery Status

Although sockeye freshwater growth tends to return to normal within two or three years following an overescapement event, there are indications that the populations are less stable for several years. The overescapement following the spill resulted in lower sockeye productivity, (as measured by return per spawner) in the Kenai River watershed from 1989-92. However, production of zooplankton in both Red and Akalura lakes on Kodiak Island quickly rebounded from the initial effects overgrazing. By 1997, Red Lake had responded favorably in terms of smolt and adult production and was at or near pre-spill production of adult sockeye. At Akalura Lake there were low juvenile growth rates in freshwater during the period 1989-92, and these years of low growth correspond to low adult escapements during the period 1994-97. Starting in 1993, however, the production of smolts per adult increased sharply and the smolt sizes and age composition suggested that rearing conditions had improved. It is possible that overescapement also affected lakes on Afognak Island and on the Alaska Peninsula. However, analysis of sockeye freshwater growth rates of juveniles from Chignik Lake on the Alaska Peninsula did not identify any impacts associated with a 1989 overescapement event. On the basis of catch data through 2001 and in view of recent analyses of return per spawner estimates presented to the Alaska Board of Fisheries in 2001, the return-per-spawner in the Kenai River system is within historical bounds. **Therefore, it is highly unlikely that the effects that reverberated from the overescapements in 1989 continue to affect sockeye salmon, and in 2002, this species was considered to be recovered from the effects of the oil spill.**

SUBTIDAL COMMUNITIES

Injury

Subtidal habitats encompass all of the seafloor below the mean lower low water tide line to about 800 meters, although deeper habitats are often referred to as the deep benthos. For purposes of this List and evaluating oil spill effects, the impacted subtidal zone generally ranges from the lower intertidal zone to a depth of about 20 meters. Communities in the near subtidal areas are typically characterized by dense stands of kelp or eelgrass and comprise various invertebrate species, such as amphipods, polychaete worms, snails, clams, sea urchins and crabs. Subtidal habitats provide shelter and food for an array of nearshore fishes, birds, and marine mammals.

It is estimated that up to 13 percent of the oil that was spilled deposited in the subtidal zones. The direct toxicity of the oil, as well as subsequent clean-up activities caused changes in the abundance and species composition of plant and animal populations below lower tides. Initial injuries were evident for several oil-sensitive species. Infaunal amphipods, a prominent prey species in subtidal communities, were consistently less abundant at oiled than at unoiled sites. Reduced numbers of eelgrass shoots and flowers were also documented and may have resulted from increased turbidity associated with clean-up activities. Two species of sea stars and helmet crabs also were less abundant at oiled sites when compared to oiled areas. However, stress tolerant organisms, including polychaete worms, snails and mussels were more abundant at oiled sites. It has been suggested that these species may have benefited from organic enrichment of the area from the oil or from reduced competition or predation because other, more sensitive species were depleted.

Recovery Objective

Subtidal communities will have recovered when community composition in oiled areas, especially in association with eelgrass beds, is similar to that in unoiled areas or consistent with natural differences between, sites such as proportions of mud and sand, and that the subtidal community and sediments found within are no longer contaminated by lingering oil.

Recovery Status

Invertebrate assemblages within eelgrass beds and adjacent areas of soft sediment, were compared at oiled and unoiled sites from 1990-1995. It was hypothesized that reduction in eelgrass and kelp could alter the habitat structure of subtidal communities and continue to impact resident species because food and shelter resources were removed from the environment. By 1995, some benthic species within eelgrass habitats of the oiled areas had recovered. However, important species such as amphipods, certain bivalves, crabs and sea stars were not as abundant at oiled sites as they were in unoiled areas. It was difficult to interpret the findings of these studies, because it was not possible to distinguish between natural conditions and differences in habitat characteristics caused by the spill or subsequent clean-up activities.

More recently, a census of marine life throughout the Gulf of Alaska measured biodiversity indices of plants and animals in the intertidal and shallow subtidal zones. Measurements of species abundance, richness and eveness were compared among areas in Prince William Sound, Kodiak Island and Kachemak Bay. Generally, community structure was significantly different between intertidal and subtidal areas with intertidal communities comprising more species and being more variable than subtidal communities. However, direct comparisons between oiled and unoiled sites were not evaluated for each community, and comparisons in these communities at a smaller scale are not known.

Concentrations of oil in subtidal areas declined by 1995, but were still slightly elevated over unoiled sites. In 2001, at a few random sites adjacent to heavily or moderately oiled intertidal areas, little or no oil was found in the subtidal sediments. However, a systematic sampling of sediments from subtidal areas in the entire spill zone has not been conducted.

In the early 90s, several benthic organisms using the subtidal zones showed trends towards recovery, and hydrocarbon concentrations had declined in many areas. **However, consistent,**

systematic surveys have not been conducted for many species, and the recovery status of subtidal communities remains unknown.

HUMAN SERVICES

COMMERCIAL FISHING

Injury

Commercial fishing was injured as a result of the spill's direct impacts to commercial fish species (see individual resource accounts) and through subsequent emergency fishing closures. Fisheries for salmon, herring, crab, shrimp, rockfish and sablefish were closed in 1989 throughout Prince William Sound, Cook Inlet, the outer Kenai coast, Kodiak and the Alaska Peninsula. Shrimp and salmon commercial fisheries remained closed in parts of Prince William Sound through 1990.

Recovery Objective

Commercial fishing will have recovered when the commercially important fish species have recovered and opportunities to catch these species are not lost or reduced because of the effects of the oil spill.

Recovery Status

In the 1994 Restoration Plan, the Trustee Council specifically recognized the declines in pink salmon and Pacific herring populations, and considered the reduction in these two fisheries as the biggest contributors to injury of the commercial fishing service in the spill area. Therefore, many restoration activities were focused towards these resources. The strategy for restoring commercial fishing included funding projects that accelerated fish population recovery, protected and purchased important habitat and monitored recovery progress. By 2002, the Trustee Council considered pink salmon and sockeye salmon to be recovered from the oil spill. However, recovery was not considered complete for Pacific herring and the recovery status of this resource remains 'not recovering' (see individual resource accounts).

Income from commercial fishing dramatically declined immediately after the spill, and for a variety of reasons, disruptions to income from commercial fishing continue today, as evidenced by changes in average earnings, ex-vessel prices and limited entry permit values. Natural variability in fish returns and a number of economic changes in the commercial fishing industry since 1989 probably mean that many of these changes in income are not directly attributable to the spill. However, these factors also make discerning spill-related impacts difficult. Economic changes confronting the industry include the increased world supply of salmon (due primarily to farmed salmonids) and corresponding reduced prices, entry restrictions in certain fisheries (such as Individual Fishing Quotas, for halibut and sablefish), allocation changes (e.g., a reduction in the allocation of Cook Inlet sockeye salmon to commercial fishermen), reduction in processing capacity, and spatial limitations of groundfish fisheries in the spill areas in conjunction with sea lion management. Finally, competition among commercial, recreational, and subsistence fishers influence management decisions of these shared resources.

No spill-related district-wide fishery closures related to oil contamination have been in effect since 1989, and populations of pink and sockeye salmon are considered recovered from the effects of the spill. However, the Prince William Sound herring fishery has been closed for 15 of the 20 years since the spill and herring are not considered recovered. **Therefore, commercial fishing, as a lost or reduced service, is in the process of recovering from the effects of the oil spill, but full recovery has not been achieved.**

PASSIVE USE

Injury

Passive use is the service provided by natural resources to people that will likely not visit, contact, or otherwise use the resource. Thus, injuries to passive use are tied to public perceptions of injured resources. Passive use is the appreciation of the aesthetic and intrinsic values of undisturbed areas and the value derived from simply knowing that a resource exists. The oil spill occurred in what many Americans viewed as an undisturbed area and caused visible injury to shorelines, fish and wildlife. The loss to passive use following the oil spill was estimated by the State of Alaska at $2.8 billion. Using a contingent valuation approach, this was the median value that those surveyed were willing to pay to prevent a catastrophe similar to the Exxon Valdez Oil Spill from happening again.

Recovery Objective

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

Recovery Status

The Trustee Council determined that passive use injuries occurred as a result of the oil spill because natural resources including scenic shorelines, wilderness areas, and popular wildlife species, from which passive uses are derived, were injured. The key to the recovery of passive use is providing the public with current information on the status of injured resources and the progress made towards their recovery.

Two vital components of the Trustee Council's restoration effort are the research, monitoring, and general restoration program and the habitat protection and acquisition program. Extensive work has been done to restore and monitor resources and communicate these findings to the public. The research, monitoring, and general restoration program is funded each year through the annual work plan, which documents the projects that are currently funded to implement restoration activities for injured resources and services. The habitat protection program preserves habitat important to injured resources through the acquisition of land or interests in land. As of 2006, the Council has protected more than 630,000 acres of habitat, including more than 1,400 miles of coastline and over 300 streams valuable for salmon spawning and rearing.

Other public information efforts in which the Council is currently engaged follows:

- The Trustee Council's web site (www.evostc.state.ak.us) offers detailed information regarding past, current, and future restoration efforts
- The Trustee Council prepares a number of documents for distribution to the public including:
    - The Invitation for Proposals, which solicits restoration project ideas from the scientific community and the public
    - The Annual Work Plan (described above)

  - o Updates to the Restoration Plan (1996, 1999, 2002, & 2006) which periodically provides new information on the recovery status of injured resources and services.
- Project final reports are available to the public at the Trustee Council's Website, through the Alaska Resource Library and Information Services (ARLIS) in Anchorage as well as at several other libraries in the State, at the Library of Congress, and through NTIS (National Technical Information Service). In addition, the Council supports researchers in publishing their project results in peer-reviewed scientific literature, which expands their audience well beyond Alaska.
- The Council supports an annual marine science symposium, which is open to the public that provides a venue in which to report the progress of restoration in the spill area.
- Public Input: The Public Advisory Committee (PAC) is an important means of keeping stakeholders and others informed of the progress of restoration and providing the public's opinions to the Trustee Council as they make decisions. Additionally, public meetings are held periodically throughout the spill area. All meetings of the Council are widely advertised and opportunity for public comment is always provided.

Until the public no longer perceives that lingering oil is adversely affecting the aesthetics and intrinsic value of the spill area it cannot be considered recovered. **Because recovery of a number of injured resources is incomplete, the Trustee Council considers services related to passive use to be recovering from the effects of the spill.**

RECREATION AND TOURISM

Injury

Recreation and tourism in the spill area dramatically declined in 1989 in Prince William Sound, Cook Inlet and the Kenai Peninsula. Injuries to natural resources led resource managers to limit access to hunting and fishing areas, and users such as kayakers were prevented from enjoying those beaches that harbored visible oil. Recreation was also affected by changes in human use in response to the spill, because areas that were unoiled become more heavily used as activity was displaced from the oiled areas.

Recovery Objective

Recreation and tourism will have recovered, in large part, when the fish and wildlife resources on which they depend have recovered, and recreation use of oiled beaches is no longer impaired.

Recovery Status

Recreation and tourism accounted for 26,000 jobs, generated $2.4 billion in gross sales and contributed $1.5 billion to Alaska's economy in 2003. The number of visitors to Alaska has increased in the years since the spill and it is expected that the recreation and tourism industry in south-central Alaska will grow approximately 28 percent per year through 2020. By 2001, over $10 million had been spent on repair and restoration of recreational facilities in the spill area, and damage caused by the spill or clean-up efforts at the Green Island cabin and Fleming Spit campsites were repaired.

Telephone interviews conducted in 1999 and 2002 of people who used the spill area for recreation before and after the spill, indicated that, although oil remained on beaches, it did not deter them from using the area. However, they continued to report diminished wildlife sightings in Prince William Sound, particularly in heavily oiled areas such as around Knight Island. They also reported seeing fewer seabirds, killer whales, sea lions, seals, and sea otters than were generally sighted before the spill, but also reported observing increases in the number of seabirds over the last several years. Key informants with experience along the outer Kenai coast reported diminished sightings of seabirds, seals, and sea lions. However, they indicated that the possible presence of residual oil has no effect on recreational activities along the outer Kenai coast, the Kodiak Archipelago, and the Lake Clark and Katmai national park coastlines. Changes in the amount of wildlife observed could be due to a variety of factors, including the spill.

Recreation and tourism rely on both consumptive and non-consumptive uses of natural resources. Although these activities have increased since the spill, several resources have not yet recovered from the spill and beaches used for recreation contain lingering oil. Resources that are important to recreation and tourism, but are still not considered recovered from the spill or their recovery is unknown include harbor seals, Kittlitz's and marbled murrelet, pigeon guillemot, clams, mussels, harlequin ducks, sea otters and killer whales. Sportfishing resources for which the recovery status is unknown are cutthroat trout and rockfish. However, the salmon species that were injured (pink and sockeye salmon) are recovered from the effects of the spill.

Even though visitation has increased since the oil spill, the Trustee Council's recovery objective requires that the injured resources important to recreation be recovered and recreational use of oiled beaches not be impaired. Lingering oil remains on beaches and in some localized areas this remains a concern for users. Moreover, several natural resources have not recovered from the effects of the spill. **Therefore, the Council finds recreation and tourism to be recovering from the effects of the spill, but not yet recovered.**

SUBSISTENCE

Injury

Fifteen predominantly Alaskan Native communities (with a total population of about 2,200 people) in the oil spill area rely heavily on harvests of subsistence resources, such as fish, shellfish, seals, deer, and waterfowl. Oil from the spill disrupted subsistence activities for the people of these villages and approximately 13,000 other subsistence permit holders in the area. Oil affected the subsistence harvests through a variety of mechanisms including reduced availability of fish and wildlife due to injury, concern about possible health effects of eating oiled fish and wildlife, and disruption of the traditional lifestyle due to clean-up and related activities.

Recovery Objective

Subsistence will have recovered when injured resources used for subsistence are healthy and productive and exist at pre-spill levels. In addition, there is recognition that people must be confident that the resources are safe to eat and that the cultural values provided by gathering, preparing, and sharing food need to be reintegrated into community life.

Recovery Status

After the spill, subsistence harvest declined between 9 – 77 percent in 10 villages within Prince William Sound, Cook Inlet and Kodiak. Villages in Tatitlek and Chenega reduced their harvest by 56 and 57 percent, respectively. Outside of the Sound, harvest declined in Akhiok (on the lee side of Kodiak Island) by nine percent, but by 77 percent in Ouzinkie, which is on the northern side of the island. The primary reason that harvest declined so dramatically was the fear that oil had contaminated the resources and made them unfit to eat.

Harvest levels have generally increased in many communities since the spill, but results of harvest surveys have been variable. By 2003, they were generally higher than pre-spill levels in the communities in Cook Inlet, but lower in Kodiak and Prince William Sound (except for Cordova). Even though the harvest levels in the PWS communities were not as high as pre-spill estimates, they were within the range of other Alaska rural communities. Harvest composition was also altered by the spill. In the first few years following the spill, people harvested more fish and shellfish than marine mammals because of the reduced number of marine mammals and the perception that these resources were contaminated and unsafe to eat.

Both safety concerns and the reduced availability of shellfish contributed to a decline in harvest levels. From 1989-94, subsistence foods were tested for evidence of hydrocarbon contamination, with no or very low concentrations of petroleum hydrocarbons found in most subsistence foods. However, concerns about oil contamination remained, and there was a belief that the increase in paralytic shellfish poisoning (PSP) was linked with *Exxon Valdez* oil. By 2003, most subsistence users expressed confidence in foods such as seals, finfish and chitons. However, the safety of certain shellfish, such as clams was still met with skepticism.

Subsistence use is a central way of life for many of the communities affected by the spill, thus the value of subsistence cannot be measured by harvest levels alone. The subsistence lifestyle encompasses a cultural value of traditional and customary use of natural resources. Following the oil spill, there was concern that the spill disrupted opportunities for young people to learn cultural subsistence practices and techniques, and that this knowledge may be lost to them in the future. In a 2004 survey of the spill area communities, 83 percent of respondents stated that their "traditional way of life" had been injured by the oil spill and 74 percent stated that recovery had not occurred.

Many factors may contribute to the changes observed in subsistence harvests and the lifestyle surrounding this tradition. Demographic changes in village populations, ocean warming, increased competition for subsistence resources by other people (e.g., sport fishing charters), predators (e.g., sea otters), and increased awareness of PSP and other contaminants may play a role in resource availability, food safety, and participation in traditional practices.

Fears about food safety have diminished since the spill, but it is still a concern for some users. Additionally, harvest levels from villages in the spill area are comparable to other Alaskan communities. However, many subsistence resources injured by the spill, including clams and mussels, have still not recovered from the effects of the spill. **For these reasons, subsistence continues to recover from the effects of the oil spill, but has not yet recovered.**

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