Exxon Valdez Oil Spill Restoration Plan

2014 Update
Injured Resources and Services

Adopted November 19, 2014

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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 *Exxon Valdez* Oil Spill (EVOS or Spill) as part of its Restoration Plan. 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 cleanup 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 to some extent, although the focus of the Council has expanded to an ecosystem approach, which is discussed below.

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 Council to pursue restoration of Spill-affected resources. However, the passage of time and the evolution of science have focused the Council's work from a listing of injured species to an ecosystem approach and this has shifted the purpose and utility of the Injured Resources and Species List. The Council recognizes that the complexities and the difficulties in measuring the continuing impacts from the Spill result in some inherent uncertainty in defining the status of a resource or service through a specific list and the Council's focus has accordingly expanded to a more ecosystem approach. The 1994 Plan also outlined an ecosystem approach to restoration and this more integrated view has become increasingly recognized as essential and the original organization of efforts through a list of species in the Update is no longer a viable approach.

In 2009, at the Twentieth Anniversary of the Spill, the Council acknowledged that funding for future restoration is limited and that it is becoming increasingly difficult to distinguish between Spill impacts and other effects in measuring recovery. Consequently, the Council's current efforts are focused on a few specific programs: (1) long-term herring research and monitoring; (2) long-term monitoring of marine conditions and injured resources; (3) shorter-term harbor protection/restoration projects; (4) lingering oil; and (5) habitat protection.

The Council also recognizes that long-term management of species and resources initially injured by the Spill lies with the agencies and entities that have the mandate and resources to pursue these long-term goals. To support natural restoration and to enable management consistent with this long-term restoration, the Council has increasingly directed funds toward research that provides information that is critical to monitor and support the healthy functioning of the Spill ecosystem.

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

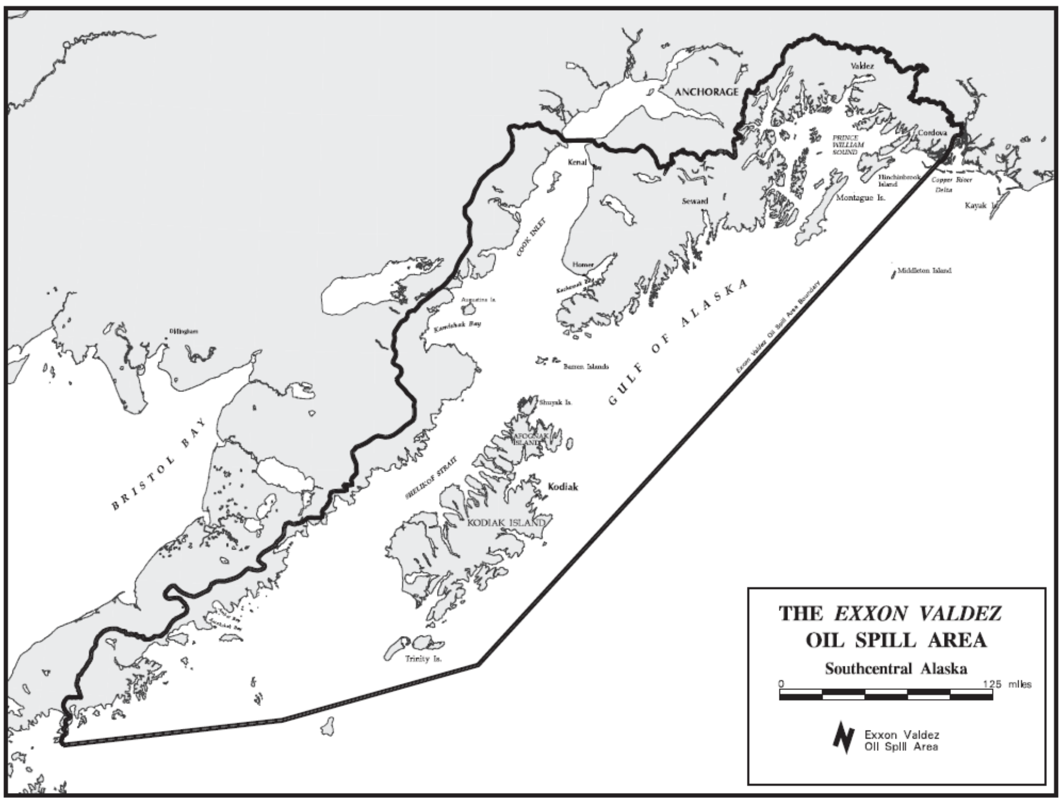

Figure 1: Map produced by: Alaska Department of Natural Resources, Land Records Information Service

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 Council. The benchmarks that were established at that time to assess the status of the resources and services injured by the oil Spill included:

- **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.

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.

Recovery Status Categories

The List has historically included four categories of recovery which are defined below. A fifth category was introduced in 2010, "Very Likely Recovered." Together, these 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.

- **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.

- **Very Likely Recovered:** While there has been limited scientific research on the recovery status of these resources in recent years, prior studies suggest that there had been substantial progress toward recovery in the decade following the Spill. In addition so much time has passed since any indications of some Spill injury, including exposure to oil; it is unlikely that there are any residual effects of the 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 unlikely that 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 cannot occur until both resources and services are restored.

List 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. In addition, in the 2006 Update 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.

- 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 2010, 21 years after the Spill, the Council again evaluated the status of injured resources and services and provided a synopsis of the most current information available. Based on the recommendations from the Science Panel and agency experts, the recovery objectives were reviewed for each resource and service to provide objectives that are potentially attainable and scientifically valid.

In 2010, a fifth Recovery Status was also added. "Very Likely Recovered" was added to reflect the status of species for which: (1) there has been limited scientific research on the resource's recovery status in recent years; (2) prior studies suggest that there had been substantial progress toward recovery in the decade following the Spill; and so much time has passed since any indications of some Spill injury, including exposure to oil, that it is unlikely that there are any residual effects of the Spill.

Barrows goldeneyes were added to the List in 2010, based on their continuing exposure to oil at that time. Lastly, the Recovery Objectives were also 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.

This 2014 Update, 25 years post-Spill, acknowledges the recovery of sea otters, Barrow's goldeneye, harlequin ducks, clams, and mussels. The 2014 Update also includes, for the first time, citations for updated information on recovery statuses.

Recovery for most injured resources has taken much longer than was originally projected. However, this Update contains a large number of resources moving to recovered status. This shift marks an important stage in recovery from the Spill. While this is a positive step forward, there remain thirteen resources and four services that are still recovering from the Spill.

Recovery Status Determination

The recovery goal for injured resources is a condition that would exist in the absence of the *Exxon Valdez* oil Spill. However, ecosystems are dynamic and the Spill-affected area would have changed even without the Spill. Given the 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 are used to assess the recovery status of a particular resource or service include:

- 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 sub-lethal 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, there is 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 there is complete knowledge of the original impacts of the oil Spill.

Uncertainties in Evaluating Recovery Status

To mitigate the uncertainties inherent in evaluating recovery, the Council reviews 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*. For many of the resources affected by the Spill there was 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.

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	2010 Status	2014 Status
Archaeological Resources	Recovering	Recovering	Recovered	Recovered	Recovered	Recovered
Bald Eagles	Recovered	Recovered	Recovered	Recovered	Recovered	Recovered
Barrow's goldeneye	N/A	N/A	N/A	N/A	Recovering	Recovered
Black Oystercatchers	Unknown	Recovering	Recovered	Recovering	Recovering	Very Likely Recovered
Clams	Unknown	Recovering	Recovering	Recovering	Recovering	Recovered
Common Loons	Unknown	Not recovering	Not recovering	Recovered	Recovered	Recovered
Common Murres	Recovering	Recovering	Recovered	Recovered	Recovered	Recovered
Cormorants	Not recovering	Not recovering	Not recovering	Recovered	Recovered	Recovered
Cutthroat Trout	Unknown	Unknown	Unknown	Unknown	Very likely recovered	Very likely recovered
Designated Wilderness	Unknown	Unknown	Recovering	Recovering	Recovering	Recovering
Dolly Varden	Unknown	Unknown	Unknown	Recovered	Recovered	Recovered
Harbor Seals	Not recovering	Not recovering	Not recovering	Recovered	Recovered	Recovered
Harlequin Ducks	Not recovering	Not recovering	Not recovering	Recovering	Recovering	Recovered
Intertidal Communities	Recovering	Recovering	Recovering	Recovering	Recovering	Recovering
Killer Whales-AB	Not recovering	Not recovering	Recovering	Recovering	Recovering	Recovering
Killer Whales-AT1	N/A	N/A	N/A	N/A	Not recovering	Not recovering
Kittlitz's Murrelets	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown
Marbled Murrelets	Not recovering	Recovering	Recovering	Unknown	Unknown	Not Recovering
Mussels	Recovering	Recovering	Recovering	Recovering	Recovering	Recovered
Pacific Herring	Not recovering	Recovering	Not recovering	Not recovering	Not recovering	Not recovering
Pigeon Guillemots	Not recovering	Not recovering	Not recovering	Not recovering	Not recovering	Not recovering
Pink Salmon	Recovering	Recovering	Recovered	Recovered	Recovered	Recovered
River Otters	Unknown	Recovered	Recovered	Recovered	Recovered	Recovered
Rockfish	Unknown	Unknown	Unknown	Unknown	Very likely recovered	Very likely recovered
Sea Otters	Not recovering	Recovering	Recovering	Recovering	Recovering	Recovered
Sediments	Recovering	Recovering	Recovering	Recovering	Recovering	Recovering
Sockeye Salmon	Recovering	Recovering	Recovered	Recovered	Recovered	Recovered
Subtidal Communities	Recovering	Recovering	Unknown	Unknown	Very likely recovered	Very likely recovered

Human Service	1996 Status	1999 Status	2002 Status	2006 Status	2010 Status	2014 Status
Commercial Fishing	Recovering[a]	Recovering	Recovering	Recovering	Recovering	Recovering
Passive Use	Recovering[a]	Recovering	Recovering	Recovering	Recovering	Recovering
Recreation & Tourism	Recovering[a]	Recovering	Recovering	Recovering	Recovering	Recovering
Subsistence	Recovering[a]	Recovering	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

More Effective Use of Remaining Funds
For some species such as rockfish and cutthroat trout, no further actions have been taken with regard to future funding of studies to assess recovery. This may be based upon the factors discussed above and may also include a consideration of the following:

1. *Additional studies expensive.* More study, with sufficient effort and scope to achieve powerful tests of the impacts of lingering oil, would be prohibitively expensive.

2. *Unable to definitively demonstrate an effect*. Natural variability, confounding effects, and a lack of tools to estimate important metrics make it unlikely that an effect could be detected with a high degree of confidence.

3. *Effects likely small.* Based on available data, mechanistic principles, and knowledge of past Spill impacts on processes of recovery, the likely effects are deemed to be minimal.

4. *Effects unlikely to be of ecological importance.* Based on available data, understanding of ecological interactions, and the expected small size of lingering impacts, it is unlikely that the effect (if any) will impair function of the ecological system.

5. *No effective restoration options available.* Even if demonstrated, there are no reasonable options for restoration of the injured resource.

6. *More effective uses of funds***.** Other projects provide promise of more definitive results, greater significance to the ecosystem, or more potential for restoration.

Ecosystem Perspective and Recovery
The List consists mainly of single species and resources, but it also provides a basis for evaluating the recovery of the overall ecosystem; its functions and the services it provides to people. Within their 1994 *Restoration Plan*, the Council adopted an ecological approach to restoration, and the studies and projects the 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 Spill. Although full ecological recovery has not been achieved, the Spill area ecosystem is making progress towards recovery 25 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 cleanup 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 cleanup 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 primarily mussels.

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 25 percent 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 low 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 are particularly vulnerable to lingering oil exposure and the potential for physiological effects. Similarly, reliance on intertidal invertebrate prey suggests that Barrow's goldeneyes are particularly vulnerable to disruptions of intertidal communities. Barrow's goldeneyes were shown to have higher levels of induction of cytochrome P4501A (CYP1A) in oiled areas compared to unoiled areas of PWS in 1996, 1997 and 2005. However, in March 2009, average CYP1A was similar between areas, suggesting that exposure to residual oil had abated by that time.

Recovery Objective

Barrow's goldeneyes will have recovered when 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. However, US Fish and Wildlife Service surveys (Cushing et al., 2012) through April 2012 show that population growth rates were the same between oiled and unoiled sites and remained relatively unchanged between 1998 and 2012.

A 2012 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 in the oiled areas, suggesting that food limitations in the intertidal zone within oiled areas were not restraining recovery. There is no evidence that Barrow's goldeneyes are currently being exposed to lingering oil in the intertidal habitat.

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.

Lack of elevated CYP1A in oiled relative to unoiled areas suggests that exposure to lingering oil has ceased in the Barrow's goldeneyes. Surveys from 2009- 2012 indicate that populations in oiled and unoiled areas have converged and the total population in Prince William Sound has remained stable since the Spill (Esler, et al. 2011). Barrow's goldeneyes are considered to be recovered from the effects of the 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 was estimated at the time of the Spill 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 cleanup 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 cleanup operations also reduced productivity on Green Island in 1990. In general, the overt effects of the Spill and cleanup 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 have reached levels that would have existed without the Spill. 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 weights 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. There have been no further studies of hatching success of black oystercatchers in Prince William Sound since this study.

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. A long-term (1989– 2007) evaluation of marine bird population trends suggested that populations of black oystercatchers in the Sound may not have recovered to conditions had the Spill not occurred, making the recovered designation premature and their status was changed to recovering in the 2010 Update. Surveys through 2012 have shown a stable population trend.

Further, oil exposure to oystercatchers was documented in 2004 using a biochemical marker of exposure, cytochrome P450IA. However, no studies since 2004 have documented continuing oil exposure.

Recent studies show no evidence of change in black oystercatcher abundance in oiled areas and no evidence that trends differ between oiled and unoiled areas (Johnson et al., 2010, Poe et al., 2009 and 2013). However, no data exists to evaluate the recovery of the hatching success in oiled or unoiled areas. Therefore we interpret the recovery status of black oystercatchers as very likely recovered.

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 shallow subtidal zones. Clams are important prey for various fish and wildlife resources including sea otters and some sea birds.

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 clean areas to oiled areas, five to seven years after the Spill.

Cleanup technologies, including hot water, high pressure washing, manual and mechanical scrubbing and physical removal of oiled sediments, were detrimental to clam populations. 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 cleanup 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 bivalves (e.g., harlequin ducks and sea otters) were still being exposed to oil.

Between 2002 and 2010, bivalve assemblages declined substantially in PWS. Recent (2012) studies indicate that the decline is in response to changes in regional conditions rather than the Spill or subsequent cleanup activities. **There are currently no differences in species richness, diversity and abundance between cleaned (oiled and treated) and untreated (oiled but untreated) beaches and**

no evidence of oil exposure in clam tissue samples. The recovery objectives have been met and clams are considered recovered.

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 1989–2007 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

Post-Spill 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, the numbers of murres at the Barren Island had increased, probably because three- and four-year old non-breeding 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 post-Spill 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 during ten of the 16 years during1989-2005. 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
Due to lack of widespread, long-term stock assessment throughout Alaska, it is difficult to assess population status and trends 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 (Nixon et al., 2013). 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.

Given the ecological similarities in summer diet and foraging ecology (Currens et al., 2003) along shorelines between cutthroat trout, juvenile pink salmon and Dolly Varden, and the absence of ongoing injury to those other two species, further research would be very unlikely to demonstrate any evidence of continuing differences between oiled and unoiled areas due to the Spill. Thus, funding the additional research necessary to provide current growth rate and abundance data for this species is not a cost-effective scientific priority.

Cutthroat trout are very likely recovered.

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 cleanup 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. In 2005 and 2012 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. The stranding of the oil on stable, boulder-armored shores or on a low-energy bedrock/boulder beach further protected the oil and slowed oil degradation processes.

Lingering oil persists in designated wilderness areas, and quantitative studies of lingering oil outside of Prince William Sound are lacking. However, in many areas, the amount of oil has diminished since 1990. Therefore, designated wilderness areas are considered to be recovering.

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 1970's 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 1970's. 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.

Harbor seals are considered recovered due to collective evidence from the last ten years indicating that harbor seal population numbers are stabilizing or increasing.

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 non-breeding-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 2010 estimate of wintering harlequin ducks in the Sound was approximately 15,425.

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 oil; 4) the possibility of oil ingestion while digging for prey in the subsurface; 5) a biochemical marker of oil exposure (cytochrome P450) was higher 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.

From 1997–2007, age composition and numerical 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 remained a disproportionately lower number of female ducks in the oiled areas. From 2000–2002, female survival rates were similar between oiled and unoiled areas. However, in 2005 through 2011 the P450 biomarker was elevated in ducks from the oiled areas (Esler et al., 2011). Finally, lingering oil appeared to remain in habitats used by harlequins, thereby maintaining the possibility of chronic effects related to continued exposure.

In 2013 studies, hepatic CYP1A levels in harlequin ducks, based on EROD activity, were similar between areas oiled during the Spill and in nearby unoiled areas (Esler, 2011 and 2013). This constitutes the first time since initiation of harlequin duck CYP1A sampling in 1998 that EROD activity has not been higher in oiled areas than in unoiled areas of Prince William Sound. This would indicate that harlequin ducks are no longer exposed to residual oil from the Spill.

Harlequin ducks are considered to be recovered, as indications of negative effects (reduced survival and declining numbers) in oiled areas have abated and breeding- and non-breeding-season demographics in oiled and unoiled areas have converged (Esler, 2013).

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 cleanup 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 cleanup activities on oiled and washed beaches showed some invertebrates, like mollusks 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.

Intertidal communities are considered to be recovering, due to the progress in the reestablishment of functioning intertidal communities.

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 appears to range only through Prince William Sound and the Kenai Fjords region. 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 20 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. 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 suggest that oil may have caused a decline immediately after the Spill.

Since 1989, a total of 15 of 22 whales have gone missing from the AT1 group and are now presumed dead (five of the carcasses were found on beaches). During that same period there has been no recruitment of calves into this genetically unique group of transients. The AT1 transients are a distinct population segment and considered depleted under the Marine Mammal Protection Act.

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 the AT1 population.

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 28. AB pod continues a slow recovery and in 1990 numbered 30 individuals, although the pod has now split and travels as two distinct units. 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 will continue to be slow. The AB pod is the only tracked pod that has experienced a decline following the Spill. Other pods have increased at an average rate of 3% per year.

Transient killer whales, such as the AT1 population, 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 seal 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 population 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 population are being influenced by factors other than residual oil which may further hinder their ability to rebound from the initial injury from the Spill.

Since 1990, the AB Pod females that survived EVOS have produced nearly as many calves as would be expected based on the number of females and their ages. The lack of recovery of AB Pod, thus, can be largely attributed to the loss of young adult females, which reduced the number of reproductive females by half, and by the loss of juveniles, such that fewer animals matured to replace the reproductive females that died. As a result, the annual birth rate in AB Pod since the EVOS has been about 70 percent the birth rate observed in other resident pods, which was significantly lower than expected, this pod is considered recovering. Full recovery can be expected over decades if recruitment rates remain positive and unexpected mortalities do not occur. The AT1 transient population of killer whales has remained stable at seven individuals with no recorded births or deaths since 2010 (Matkin, 2013) and is considered not recovering. Progress toward recovery appears unlikely as key breeding females have been lost and no new recruitment observed.

The AB killer whale pod is considered to be recovering due to the low but stabilized reproduction rate of the pod. The recovery status of the AT1 killer whale population is considered to be not recovering due to a lack of recruitment of breeding females.

KITTLITZ'S MURRELETS

Injury
The Kittlitz's murrelet is found only in Alaska and 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 (PWS). The Kenai Peninsula coast, lower Cook Inlet 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 has recovered to a level had the Spill not occurred. Stable or increasing productivity within normal bounds will be an indication that recovery is underway.

Recovery Status
While studies of Kittlitz's murrelets were conducted in the 2000s, our knowledge of their ecology and trends remains limited. They are known to nest in montane areas historically or actively shaped by glacial action and are thought to reside within PWS from May through August. Nesting has been reported from around the PWS region, as well as the Kenai and Alaska Peninsulas, and Kodiak Island.

Kittlitz’s murrelets lay a single egg and have an intrinsically low population growth rate, thus recovery from an acute loss is likely to be slow.

Kittlitz’s murrelets have shown evidence of steep declines, which began before the Spill. The rate of decline between 1972 and 2007 was -18% per year, but if measured between 1989 and 2007, the rate of decline was -31% per year (Kuletz et al., 2011a). Estimating population trends for this species is complicated, however, because of the small population size, patchy distribution, and difficulty in distinguishing the rare Kittltiz’s murrelet from the more abundant marbled murrelet. Data from EVOSTC surveys in PWS from 2010 and 2012 (Cushing et al., 2012) suggest a possible stabilization of Kittlitz’s murrelets at a lower population size.

Natural recovery has not restored this resource to levels that would have existed had the Spill not occurred. What little evidence is available from studies in Alaska suggest possible predator limitation in some areas, and lack of productivity due to food availability and chick predation. A 2014 study has also found that paralytic shellfish poisoning has contributed to chick mortality at nest sites on Kodiak Island (Shearn-Bochsler et al., 2014). While it is likely that basic biological studies would be useful to understand what may be limiting recovery, these confounding effects make it unlikely that further study will clarify whether there are still residual effects of the Spill. In addition, the rarity of this species makes it difficult and expensive to study.

While the population decline appears to have abated, Kittlitz’s murrelets have not met their recovery objective and, due to the factors discussed above, their current recovery status remains unknown.

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 recovered. 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 cleanup 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. In PWS, it is estimated that marbled murrelets declined at a rate of 5% per annum from 1989-2012, a cumulative population loss of -69% (Cushing et al., 2012, Piatt et al., 2007). 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.

Marbled murrelets rely on forage fish such as Pacific herring and Pacific sand lance, which may be declining in the Spill area due to various reasons. Their dietary preferences and foraging areas make significant contact with lingering oil unlikely and there are no differences in population trends between oiled and unoiled areas. Exogenous factors such as climatic factors, decreases in habitat availability, and shifts in forage fish populations are the most likely drivers of murrelet population dynamics.

Marbled murrelets have not met their recovery objective of an increasing or stable population. They are considered to be not recovering from the effects of the Spill.

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 cleanup 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 unoiled 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 and 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.

Data from 2012 indicated that hydrocarbon concentrations in mussels, even on armored beaches where elimination has been slow, are not different from background (Fukuyama et al., 2014; Lees et al., 2012).

As mussels have met all of their goals for recovery, they are considered recovered from the effects of the 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. 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 23,000 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 19 of the 25 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 research suggests that the opening of the fishery in 1997 and 1998 stressed an already weakened population and may have contributed to the 1999 decline. The fishery has been closed since then and no trend suggesting healthy recovery has occurred.

One of the factors currently limiting recovery of herring in the Sound appears 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. While these diseases can occur at background levels, they do not usually impact fish populations for such a long duration.

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 has been hypothesized 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.

Other factors may have contributed to the crash of 1993. Some evidence implies that zooplankton production in the 1990's was less than in the 1980's, 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 pressures of predation and disease, ADF&G biomass forecasts in 2010, 2011 and 2012 exceeded the commercial fishing threshold of 22,000 tons (Botz et al., 2011, 2012 and 2013). However, they did not provide a large enough harvestable surplus to allocate fish among all five herring fisheries: purse seine sac roe, gillnet sac roe, spawn-on-kelp not in pounds, spawn-on-kelp in pound fisheries, and herring food/bait fishery. Hindcasts from the 2013 forecast model for 2011 and 2012 were below the regulatory threshold with 2013 having the lowest mile-days of spawn in PWS since 1973 (Dressel, pers.comm.).

A combination of factors, including disease, predation and poor recruitment appear to contribute to the continued suppression of herring populations in the Sound. No strongly successful year class has been recruited into the population and health indices suggest that herring in the Sound are not fit. However, the biomass has remained relatively stable over the past seven years but at a lower tonnage than can support a sustainable commercial fishery.

Pacific herring have not yet met their recovery objectives and are considered not recovering from the effects of the Spill.

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.

In 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.

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.

The pigeon guillemot population continues to decline in both oiled and unoiled areas of Prince William Sound (Ben-David, 2012a and 2012b). Nest predation is a potential source of mortality that may be limiting recovery in some areas, implying that predator removals could prove an effective restoration option. More data on productivity levels is needed to determine if the recovery objective of increasing abundance and productivity has been met.

A project to determine if mink predation is a limiting factor in the nesting success of PIGU on the Naked Island complex began in 2014 and will continue through 2015 (Ben-David, 2012a and 2012b).

Pigeon guillemots are considered to be not recovered 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 are 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.

Rockfish are managed by the Alaska Department of Fish and Game for recreational fishing and the North Pacific Fisheries Management Council for commercial fishing in PWS. Data collected by both groups in the years since the Spill (Wessel et al., 2014 and NPFMC, 2014) indicate that the population is healthy in Prince William Sound and have shown no biomarkers of oil exposure. There have been no demonstrated differences in population or breeding success between oiled and unoiled areas.

As there is no defined recovery objective, we used objectives set by other injured resources to determine the rockfish's recovery status. We consider rockfish to be very likely recovered.

SEA OTTERS

Injury

Sea otters were originally found throughout the north Pacific including Japan, Russia, the United States, Canada and Mexico. By the late 1800s, they had been eliminated from most of their range due to over-harvest by fur traders. Sea otters came under international protection in 1911 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.

More than a thousand 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 (PWS). 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 persisted for well over a decade.

Recovery Objective
Sea otters will have recovered when the population in oiled areas returns to conditions that would have existed had the Spill not occurred 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 remained well below pre-Spill numbers, and population trends continued to decline through 2010. Moreover, the demographics within this group apparently were not stable as many of the females are below reproductive age and young, non-territorial males moved into and out of the population.

However, the aerial surveys in 2013 (Esler, 2013) indicated that population abundance in Prince William Sound have converged in oiled and unoiled areas. The estimated number of sea otters more than doubled relative to the 1993 estimate and the increase over that time frame was greater to or similar to estimates of sea otters that died within the first years of the Spill. The 2013 surveys indicated that the sea otter population at heavily-oiled northern Knight Island, where abundance was depressed for two decades after the Spill, had finally reached pre-Spill levels.

Starting in 2011, there was a distinct change in the age-class proportions of dying sea otters, with a return to the pre-Spill pattern of predominantly young and older sea otters recovered as carcasses. This pattern continued in 2012 and 2013, which may be interpreted as evidence that from 2011 - 2013, chronic exposure to lingering oil and/or chronic effects due to previous exposure abated to the point where they are no longer factors constraining survival (Esler, 2011 and 2013).

Overall, the current population level data for sea otters in PWS are consistent with the EVOSTC definition of recovery for sea otters from the long-term injury incurred in the wake of the 1989 oil Spill. The support for this is based primarily on demographic data, including (1) a return to estimated pre-Spill abundance of sea otters at northern Knight Island, a heavily-oiled area within PWS, and (2) a return to pre-Spill mortality patterns based on ages-at-death. Gene transcription rates in 2012 were similar in sea otters from oiled, moderately-oiled and unoiled areas, suggesting abatement of exposure effects in 2012. However, because 2012 gene transcription rates generally were low for sea otters from all areas relative to 2008, these observations cannot be fully interpreted without data from a wider panel of genes. This slight uncertainty with respect to the data from the biochemical indicator is outweighed by the strength of the data for the demographic indicators. The return to pre-Spill numbers and mortality patterns suggests a gradual dissipation of exposure to lingering oil over the past two decades, to the point where continuing exposure is no longer of biological significance to the PWS sea otter population (Ballachey et al., 2014).

Therefore, sea otters are considered to be recovered.

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. Cleanup activities also occurred in 1990 and 1991. According to Shoreline Cleanup 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 cleanup 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 cleanup 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 examining the extent of subsurface shoreline oiling in PWS and the Gulf of Alaska included selection of sites that had any level of initial oiling for field surveys. Known field data were combined with modeling to estimate the extent of oiled shoreline at that point. An earlier estimate of the amount of oil remaining was that 200 tons of oil might still exist. Given the slow loss rate of subsurface oiling that estimate may still be reasonable.

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 1992–2012. 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 2012, 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.

Twenty-five years after the Spill, lingering oil persists 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 (Boufadel, 2012).

Therefore, sediments are still considered to be recovering.

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.

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 cleanup 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 cleanup 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 cleanup 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 evenness 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 1990's, 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. Given the length of time since evidence of injury was last documented, the lack of subtidal oil for many years, and the resiliency and short generation times for the species that had shown lower populations in the oiled areas, it seems likely that recovery has occurred.

Subtidal communities are very likely recovered. In addition, further study, with sufficient effort and scope to achieve powerful tests of the impacts of lingering oil, would be relatively expensive and unlikely to definitively demonstrate an effect of the oil Spill on this resource.

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.

Since 1989, there have been no non-herring, Spill-related, district-wide fishery closures related to oil contamination, and populations of pink and sockeye salmon are considered recovered from the effects of the Spill. The Prince William Sound herring fishery has been closed for 19 of the 25 years since the Spill and herring are still considered to be recovering recovered.

Commercial fishing, as a lost or reduced service, is considered to be recovering from the effects of the oil Spill.

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. This includes two long-term monitoring programs. 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 website (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:
- An Invitation for Proposals, issued at five-year intervals, which solicits restoration project ideas from the scientific community and the public for the Council's restoration activities, including two long-term monitoring programs,
- The Annual Work Plan (described above),
- 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.
- 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.

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 recreational 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 cleanup 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 Kittlitz's and marbled murrelets, pigeon guillemots, and killer whales. Sport fishing resources that affected recreation and tourism are now either very likely recovered (cutthroat trout) or recovered (rockfish and pink and sockeye salmon).

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, some of the natural resources upon which recreation and tourism rely have not recovered from the effects of the Spill.

Therefore, the Trustee 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 cleanup and related activities.

Recovery Objective

Subsistence will have recovered when injured resources used for subsistence are healthy and productive and exist at sustainable 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 re-integrated 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 2006, 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.

For these reasons, subsistence is considered to be recovering from the effects of the oil Spill.

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