Exxon Valdez Oil Spill Restoration Plan

Update on Injured Resources and Services

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Update on Injured Resources and Services
Introduction

History and Purposes of the List

In November 1994, the Trustee Council adopted an official list of Injured Resources and Services Injured by the Spill as part of the *Restoration Plan*. This list serves three main purposes:

1. It is representative of injuries caused by the oil spill and cleanup efforts and helps the Trustees and the public track the status of important fish, wildlife, and other resources and services. The fish and wildlife on this list are thought to have suffered population-level or sublethal injuries, but it does not include every species or resource that suffered some degree of injury. For example, carcasses of about 90 different species of oiled birds were recovered in 1989, but only 10 species of birds are on the list of injured species.

2. It helps guide priorities for implementation of the *Restoration Plan*. This was especially important in 1994 when the plan was first adopted, but the list still serves to highlight resources that are in need of attention. For example, what additional work can be undertaken to clarify the status of recovery-unknown resources, or what can be done, if anything, to help move resources from not recovering to recovering or from recovering to recovered?

3. Finally, taken as a whole, the list of injured resources helps the Trustees and the public track recovery of the overall ecosystem and the functions and human services that it provides. For example, neither the ecosystem nor the service of commercial fishing can be judged to have recovered from the effects of the oil spill until keystone resources, such as Pacific herring, are themselves fully recovered.

Chapter 4 of the *Restoration Plan* indicates that the Injured Resources and Services list will be reviewed periodically and updated to reflect what is learned from scientific studies and other sources of information, such as from traditional and local knowledge. Each time the list is reviewed, a resource's progress or lack of progress toward recovery is evaluated with reference to a recovery objective that is as concrete and measurable as possible. Sometimes the recovery objectives themselves are changed to reflect new insights about the nature of the injury and the best ways to evaluate recovery status. The table on page 3 includes brief descriptions of what each recovery category means.

The Injured Resources and Services list was first updated in September 1996. At that time, for example, the bald eagle was upgraded from recovering to recovered. In 1999, 10 years after the oil spill, several more changes have been made. The river otter is now considered to be recovered, and five resources—black oystercatcher, clams, marbled murrelet, Pacific herring, sea otter—are upgraded to recovering. One resource, common loon, is moved from recovery unknown to not recovering. Five resources remain as recovery unknown. Four human services are classified as recovering.

The Injured Resources and Services list can be updated at any time that new information becomes available. It is likely, however, that the next evaluation of changes in recovery status for all injured resources and lost or reduced services will be in 2001, 10 years after the 1991 settlement between the governments and Exxon and initiation of the restoration program.

Ecosystem Perspective and Recovery

The List of Injured Resources consists mainly of single species and resources, but, as noted above, it provides a basis for evaluating the recovery of the overall ecosystem, its functions, and the services that it provides to people. In fact, through the *Restoration Plan*, the Trustee Council adopted an ecological approach to restoration, and the studies and projects it sponsors have been increasingly ecological in character.

Page 35 of 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 prespill 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.

Resources and Services Injured by the Spill

Not Recovering

Species are showing little or no clear improvement since spill injuries occurred.

Common loon
Cormorants (3 spp.)
Harbor seal
Harlequin duck
Killer whale (AB pod)
Pigeon guillemot

Recovering

Substantive progress is being made toward recovery objective. The amount of progress and time needed to achieve recovery vary depending on the resource.

Archaeological resources
Black oystercatcher
Clams
Common murres
Intertidal communities
Marbled murrelets
Mussels
Pacific herring
Pink salmon
Sea otter
Sediments
Sockeye salmon
Subtidal communities

Recovered

Recovery objectives have been met.

Bald eagle
River otter

Resources in boldface have each moved on this Recovery Line during the most recent update (February 9, 1999)

Recovery Unknown

Limited data on life history or extent of injury; current research inconclusive or not complete.

Cutthroat trout
Designated
Wilderness Areas
Dolly Varden
Kittlitz's murrelet
Rockfish

Photo by Roy Corral

Human Services

*Human services that depend on natural resources were also injured by the oil spill. These services are each considered to be **recovering** until the resources on which they depend are fully recovered.*

Recreation & tourism
Commercial fishing
Passive uses
Subsistence

Using this definition, the coastal and marine ecosystem in the oil-spill region has not recovered from the effects of the oil spill. Keystone species, such as Pacific herring and harbor seals, have not fully recovered, nor has the composition of biological communities, such as in intertidal habitats. Although full ecological recovery has not been achieved, the spill-area ecosystem is still largely intact and functioning and on the way to recovery 10 years after the *Exxon Valdez*.

It also is important to understand that ecosystems are dynamic and would have changed even in the absence of the oil spill. Baseline data describing fish and wildlife populations, to say nothing of complex intertidal and subtidal communities, were generally poor. For this reason, it was and is difficult to evaluate injury to individual resources and the ecosystem in general, and an inability to document injury because of poor baseline data does not mean that injury does not exist. It also is important to note that as the time since the oil spill grows longer, it is more and more 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. In fact, what we see is often an interaction between oil effects and natural changes, such as the effects of the 1998 El Niño on common murres in the Barren Islands.

Photo by Roy Corral

Contents

Injured Resources

Archaeological Resources 5
Bald Eagles 5
Black Oystercatchers 6
Common Loons 6
Clams 7
Common Murres 7
Cormorants 8
Cutthroat Trout 8
Designated Wilderness Areas 9
Dolly Varden. 9
Harlequin Ducks 10
Harbor Seals 11
Intertidal communities 11
Kittlitz's Murrelets 12
Killer Whales 12
Marbled Murrelets 14
Mussels 14
Pacific Herring 15
Pigeon Guillemots 16
Pink Salmon 16
River Otters 17
Rockfish 18
Sea Otters 18
Sediments 19
Sockeye Salmon 19
Subtidal Communities 20

Human Services

Commercial Fishing 21
Passive Uses 22
Recreation and Tourism 24
Subsistence 25

Archaeological Resources

Injury and Recovery

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 include 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, vegetation was disturbed, which exposed sites to accelerated erosion. The effect of oil on soil chemistry and organic remains may reduce or eliminate the utility of radiocarbon dating in some sites.

Assessments of 14 sites in 1993 suggested that most of the archaeological vandalism that can be linked to the spill occurred early in 1989, before adequate constraints were put into place over the activities of oil spill clean-up personnel. Most vandalism took the form of "prospecting" for high yield sites. Once these problems were recognized, protective measures were implemented and successfully limited additional injury. In 1993, only two of the 14 sites visited showed signs of continued vandalism. In 1996, there was evidence of vandalism at five sites, but only at one site in 1997. Natural erosion is the major agent of degradation at the sites, and the erosion draws the attention of looters to the exposed artifacts. Nine years after the oil spill it is difficult to attribute the recent cases of vandalism to discovery of these sites at the time of the oil spill.

Oil was visible in the intertidal zones of two of the 14 sites monitored in 1993, and hydrocarbon analysis has shown that the oil at one of the sites was from the *Exxon Valdez* spill. Hydrocarbon concentrations at the second site were not sufficient to permit identification of the source or sources of the oil. 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.

In 1993, the Trustee Council provided part of the construction costs for the Alutiiq Archaeological Repository in Kodiak. This facility now houses Kodiak-area artifacts that were collected during the time of spill response. Artifacts recovered from injured sites in lower Cook Inlet and Prince William Sound currently are stored at the University of Alaska Fairbanks or elsewhere. In 1999, however, the Trustee Council approved funding for an archaeological repository and local display facilities for artifacts from Prince William Sound and lower Cook Inlet.

Two sites in Prince William Sound were so badly damaged by oiling and erosion that they were partly documented, excavated, and stabilized by professional archaeologists in 1994-1997. It appears that the two sites were intermittently occupied for periods of 2,000 and 3,000 years. Most of the cultural deposits are prehistoric in nature.

Starting in 1996, the Trustee Council funded a project to involve local residents in monitoring and protecting vulnerable sites in the Kenai, Homer, Seldovia, Kodiak, and Chignik areas. This project was based on the premise that successful long-term stewardship depends on community support and involvement. A report on this project is due in 1999. **Based on the apparently low rate of spill-related vandalism and progress in the preservation of artificats and scientific data on archaeological sites and artifacts, archaeological resources are considered to be recovering.**

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 prespill levels, and the artifacts and scientific data remaining in vandalized sites are preserved (e.g., through excavation, site stabilization, or other forms of documentation).

Bald Eagles

Injury and Recovery

The bald eagle is an abundant resident of marine and riverine shoreline throughout the oil-spill area. Following the oil spill, a total of 151 eagle carcasses was 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. Productivity was back to normal in 1990 and 1991, and an aerial survey of adults in 1995 indicated that the population had returned to or exceeded its prespill level in the sound.

In September 1996, the Trustee Council classified the bald eagle as fully recovered from the effects of the oil spill. No additional work has been carried out specifically to assess the status of the bald eagle. However, the bald eagle has benefited enormously from the habitat protection program, including the acquisition of more than 1,200 miles of marine shoreline and 280 anadromous fish streams.

Recovery Objective

Bald eagles will have recovered when their population and productivity have returned to prespill levels.

Black Oystercatchers

Injury and Recovery

Black oystercatchers spend their entire lives in or near intertidal habitats and are highly vulnerable to oil pollution. It is estimated that 1,500-2,000 oystercatchers breed in south-central Alaska. Only nine carcasses of adult oystercatchers were recovered following the spill, but the actual number of mortalities may have been considerably 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.

From 1991-1993, the Trustee Council sponsored a study to determine if there were any persistent effects of the spill on breeding success and feeding ecology of black oystercatchers on Knight Island. Adult oystercatchers foraged in oiled mussel beds, but also obtained invertebrate prey at unoiled sites. As late as 1993, there was direct evidence of hydrocarbon exposure from fecal samples of chicks raised on persistently oiled shorelines, but areas of contamination were patchily distributed and relatively few adults and young were exposed. In 1989, chicks raised on oiled shorelines gained weight more slowly than chicks reared on unoiled shores, but the slower weight gain was not manifested in reduced fledging success. Surveys from 1991-1993 indicated that the population inhabitating Knight Island was not increasing. Hydrocarbon exposure has not been tested since 1993.

Productivity and survival of black oystercatchers in Prince William Sound were not monitored from 1993 through 1997. Boat-based surveys of marine birds in the sound did not indicate recovery in numbers of oystercatchers in oiled areas through 1998, but these surveys were not specifically designed to monitor oystercatchers.

In 1998 the Trustee Council sponsored a study to reassess the status of this species in Prince William Sound. Only preliminary results are available, but these data indicate that oystercatchers have fully reoccupied and are 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. A high rate of nest failures on Green Island probably can be attributed to predation, not lingering effects of oil. **Given general agreement between these new results and those of the earlier work, which indicated that the effects of the spill had largely dissipated by 1991, recovery of black oystercatchers clearly is underway.**

Black oystercatchers nest on rocky beaches and have benefited enormously from the habitat protection program, including the acquisition of more than 1,200 miles of marine shoreline. In addition, introduced foxes were eliminated from two of the Shumagin Islands (Simeonof and Chernabura) in the southwestern part of the spill area. Black oystercatchers were present in low densities on both islands, and in higher densities on nearby fox-free islands. Although the nesting birds have not been surveyed since 1995, when the last of the foxes was removed, the elimination of the introduced predators should increase populations of nesting oystercatchers.

Recovery Objective

Black oystercatchers will have recovered when the population returns to prespill levels and reproduction is within normal bounds. An increasing population trend and comparable hatching success and growth rates of chicks in oiled and unoiled areas, after taking into account geographic differences, will indicate that recovery is underway.

Common Loons

Injury and Recovery

Carcasses of 395 loons of four species were recovered following the spill, including at least 216 common loons. Current population sizes in the spill area are not known for any of these species. 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.

Boat-based surveys of marine birds in Prince William Sound give at least some insight into the recovery status of the loons affected by the oil spill. These surveys indicated that the oil spill had a negative effect on numbers of loons (all species combined) in the oiled parts of the sound in 1991. Based on the surveys carried out through 1998, there is no indication of recovery. Further, a comparison of July 1984 versus July 1990-98 survey data suggests that loons (all species) show a pattern of increasing densities in unoiled parts of the sound and essentially stable densities in oiled parts of the sound. This disparity is consistent with possible lack of recovery from an oil-spill effect. **Thus, the common loon is considered to have not recovered from the effects of the spill.** No additional information on the status of common loons is available.

Recovery Objective

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

Clams

Injury and Recovery

The magnitude of immediate impacts on clam populations varied with the species of clam, degree of oiling, and location. Data from the lower intertidal zone on sheltered beaches suggested that littleneck clams and, to a lesser extent, butter clams were killed and suffered slower growth rates as a result of the oil spill and cleanup activities.

Since the original damage assessment work on clams in 1989 and 1990, the Trustee Council has not sponsored additional studies focused specifically on clam injury and recovery. Some insights are available from projects carried out by the NOAA Hazardous Materials Division and others on intertidal and subtidal communities in relation to oil and shoreline treatments. In general, these studies indicate that intertidal fauna dwelling in soft sediments, including various clam species, had rebounded within one-three years after 1989 on oiled-but-untreated shorelines. On these shorelines, abundances or trends in abundance of intertidal fauna were parallel or similar to those at unoiled, untreated sites. One study documented that concentrations of hydrocarbons in littleneck clam tissues at oiled and unoiled sites were not significantly different by 1993. These results indicate that recovery is underway.

Clearly, however, full recovery has not been achieved, especially on shorelines that were oiled and treated by hot-water washes. For example, one study found that densities of littleneck and butter clams were depressed through 1996 on oiled, treated mixed-sedimentary shores where fine sediments had been washed downslope during pressured water treatments. Comparing oiled study sites on Knight Island with unoiled sites on Montague Island, researchers in the Nearshore Vertebrate Predator project found a full range of size classes of clams at the oiled sites, as well as more large clams. However, oiled sites also had fewer juvenile clams and lower numbers of several species. **Based on all of the evidence summarized above, clams are recovering, but are not yet fully recovered from the effects of the oil spill.**

In communities on the Kenai Peninsula, Kodiak Island, the Alaska Peninsula and in Prince William Sound there are lingering concerns about the effects of the oil spill on clams. The Trustee Council sponsored a project to help restore subsistence uses of clams (see subsistence).

Recovery objective

Clams will have recovered when populations and productivity have returned to levels that would have prevailed in the absence of the oil spill, based on comparisons of oiled and unoiled sites.

Common Murres

Injury and Recovery

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 population 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 reduced. Interpretation of the effects of the spill, however, is complicated by incomplete prespill data and by indications that populations at some colonies were in decline before the oil spill.

Postspill monitoring at the breeding colonies in the Barren Islands indicated that reproductive success was again 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 2-5 days each year, suggesting that the age and experience of nesting birds was increasing, as might be expected after a mass mortality event. By 1997, numbers of murres at the Barren Islands had increased, probably because 3-and 4-year old nonbreeding subadult birds that were hatched there in 1993 and 1994 were returning to their natal nesting colony. **This information suggests that recovery is well underway, although the strong 1998 El Niño event apparently disrupted timing and synchrony of nesting at the Barren and Chiswell islands and may, to some extent, have affected reproductive success.** The Barren Islands colonies will be surveyed again in 1999.

Although Prince William Sound does not have a large summer population of murres, boat-based surveys of marine birds before and after the oil spill indicated a negative effect on numbers in the sound. Surveys carried out through 1998 have not shown any increase in murres since the spill.

The Alaska Predator Ecosystem Experiment (APEX project), funded by the Trustee Council, is investigating the linkage between murre populations and changes in the abundance of forage fish, such as Pacific herring, sand lance, and capelin. Historical trawl data analyzed as part of this project supported a decision by the North Pacific Fishery Management Council to limit bycatch of forage fish in commercial fisheries and to preclude the startup of fisheries targeting forage fish (not including herring).

Recovery Objective

Common murres will have recovered when populations at index colonies have returned to prespill levels and when productivity is sustained within normal bounds. Increasing population trends at index colonies will be a further indication that recovery is underway.

Cormorants

Injury and Recovery

Cormorants are large fish-eating birds that spend much of their time on the water or perched on rocks near the water. Three species 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. Many more cormorants probably died as a result of the spill, but their carcasses were not found.

No regional population estimates are available for any of the cormorant species found in the oil-spill area. In 1996, the U.S. Fish and Wildlife Service Alaska Seabird Colony Catalog, however, listed counts of 7,161 pelagic cormorants, 8,967 red-faced cormorants, and 1,558 double-crested cormorants in the oil-spill area. These are direct counts at colonies, not overall population estimates, but they suggest that population sizes are small. In this context, it appears that injury to all three cormorant species was significant.

Counts on the outer Kenai Peninsula coast suggested that the direct mortality of cormorants due to oil resulted in fewer birds in this area in 1989 compared to 1986. In addition, there were statistically-significant declines in the estimated numbers of cormorants (all three species combined) in the oiled portion of Prince William Sound based on pre- and postspill boat surveys in July 1972-73 compared to 1989-91. **More recent surveys (through 1998) have not shown an increasing population trend since the oil spill, and for that reason these species are considered to be not recovered.**

Recovery Objective

Pelagic, red-faced, and double-crested cormorants will have recovered when their populations return to prespill levels in the oil-spill area. An increasing population trend in Prince William Sound will indicate that recovery is underway.

Cutthroat Trout

Injury and Recovery

Prince William Sound is at the northwestern limit of the range of cutthroat trout. Local cutthroat trout populations are believed to be small, and the fish have small home ranges and are geographically isolated. Cutthroat trout, therefore, are highly vulnerable to exploitation, habitat alteration, or pollution.

Following the oil spill, cutthroat trout in a small number of oiled index streams in Prince William Sound grew more slowly than in unoiled streams. The apparent difference in growth rates persisted through 1991. 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.

Preliminary data from a Trustee Council-sponsored study of resident and anadromous forms of cutthroat trout in Prince William Sound suggest that there is significant genetic variation among trout from different locations across the sound. These data are consistent with the idea that cutthroat populations are small and isolated. This work is being completed in FY 1999 and should make possible insights into such issues as growth rates with respect to geographic variation. **Pending this additional work, the recovery status of the cutthroat trout remains unknown.**

Photo by Roy Corral

Cutthroat Trout

Cutthroat trout have benefited from several other projects sponsored by the Trustee Council. In 1991-93, in response to the early evidence of injury to cutthroat trout, sport harvests were temporarily restricted in Prince William Sound. In 1994, out of concern about the long-term conservation status of this species, the Alaska Board of Fisheries permanently closed sport harvests during the April 15-June 15 spawning season in the sound.

The Trustee Council sponsored inventories of streams in and around Prince William Sound to identify cutthroat trout habitat and the presence or absence of this species. Information from these inventories has been added to the Alaska Department of Fish and Game's Anadromous Waters Catalog, and this step brings to bear additional legal protection under state law in regard to actions affecting these streams. Additional habitat for cutthroat trout has been protected from among the more than 280 anadromous fish streams that have been acquired through the Trustee Council's habitat protection program.

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.

Designated Wilderness Areas

Injury and Recovery

The oil spill delivered oil in varying quantities to the waters and tidelands adjoining eight areas designated as wilderness areas and wilderness study areas by Congress or the Alaska State Legislature. Oil also was deposited above the mean high-tide line at these locations. During the intense clean-up seasons of 1989 and 1990, thousands of workers and hundreds of pieces of equipment were at work in the spill zone. This activity was an unprecedented imposition of people, noise, and activity on the area's undeveloped and normally sparsely occupied landscape. Although activity levels on these wilderness shores have probably returned to normal, at some locations there is still residual oil.

Kenai Fjords National Park *Photo by Roy Corral*

Among the 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. Six moderately to heavily oiled sites on the Kenai and Katmai coasts were last surveyed in 1994, at which time some oil mousse persisted in a remarkably unweathered state on boulder-armored beaches at five sites. These sites will be visited again in 1999. **Pending completion of these visits, and additional visits to oiled shorelines in western Prince William Sound, the recovery status of designated wilderness remains unknown.**

Recovery Objective

Designated wilderness areas will have recovered when oil is no longer encountered in them and the public perceives them to be recovered from the spill.

Dolly Varden

Injury and Recovery

Dolly Varden are widely distributed in the spill area. In spring, anadromous forms of Dolly Varden migrate to the sea from the lakes and rivers where they spend the winter. Summers are spent feeding in nearshore marine waters. Thus, some Dolly Varden in Prince William Sound and perhaps at other locations were exposed to *Exxon Valdez* oil in 1989 and possibly beyond. In fact, concentrations of hydrocarbons in the bile of Dolly Varden were some of the highest of any fish sampled in 1989. By 1990, these concentrations had dropped substantially.

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. However, these growth differences did not persist into the 1990-91 winter. No growth data have been gathered since 1991.

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 summers in saltwater. This hypothesis is supported by preliminary data from another Trustee Council-sponsored study, which indicates that Dolly Varden from different locations across the sound are genetically similar. The final report on this genetics study is due in 1999, but if this preliminary conclusion is born out, it would suggest that the Dolly Varden population in the sound should have little difficulty in recovering from any initial growth-related effects. **Pending completion of the genetics work and absent additional growth data, however, it is prudent to continue classifying the Dolly Varden as recovery unknown.**

The Trustee Council sponsored inventories of streams in and around Prince William Sound to identify Dolly Varden habitat and the presence or absence of this species. Information from these inventories has been added to the Alaska Department of Fish and Game's Anadromous Waters Catalog, and this step brings to bear additional legal protection under state law in regard to actions affecting these streams. Additional habitat for Dolly Varden has been protected from among the more than 280 anadromous fish streams that have been acquired through the Trustee Council's habitat protection program.

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.

Harlequin Ducks

Injury and Recovery

Harlequin ducks feed in intertidal and shallow subtidal habitats where most of the spilled oil was initially stranded. More than 200 harlequin ducks were found dead in 1989, mostly in Prince William Sound. Many more than that number probably died throughout the spill area. Because the spill occurred in early spring before wintering harlequins migrated from the sound to inland breeding sites, the initial effects of the spill were likely extended beyond the immediate spill zone. The geographic extent of these extended impacts is not known.

The current overwintering population of harlequin ducks in Prince William Sound is on the order of 18,000 ducks, while the summer population is about half that number. Fall boat surveys designed specifically to monitor molting-wintering harlequin ducks indicate a significant declining trend in the western sound. Other boat surveys designed to monitor an entire suite of marine birds in the sound have shown mixed results: an increasing trend in March but no increase in July through 1996. All three surveys, however, are consistent in that they show different or lower trends for harlequin ducks in oiled parts of the sound compared to unoiled parts.

Prespill data on harlequin populations and reproductive success are limited and difficult to interpret, but previously there was concern about poor reproductive success in the western versus eastern parts of Prince William Sound. This concern was based on observations of 7-15 broods in the eastern sound and few-to-no reports of broods in the western sound when comparable numbers of streams were surveyed. Subsequent research does not indicate any differences in the age- and sex-structure of harlequin populations in the eastern and western parts of the sound, but it is clear that the breeding habitat in the western sound is very limited compared to what is available in the eastern sound. Some harlequins remain in the sound to nest, mostly on the eastern side, but it is now suspected that most harlequins of breeding age and condition probably leave the sound altogether to nest in interior drainages. Thus, conclusions of reproductive failure based on lack of broods in the oiled area do not now seem warranted.

Biopsies from samples of harlequin ducks collected early in 1998 and from Barrow's goldeneye in the 1996-1997 winter continue to show differences in an enzyme indicative of exposure to hydrocarbons between birds from oiled versus unoiled parts of the sound. These differences are consistent with the possibility of continued exposure to hydrocarbons in the oiled western sound. The biological effect of this possible exposure has not been established, but three years of data (1995/96-97/98 winters) on overwintering survival of adult female harlequins indicate significantly lower survival rates in oiled versus unoiled parts of the sound. This result cannot be attributed unequivocally to oil exposure, but there is reason for concern about possible oil exposure and reduced survival for harlequin ducks in the western sound. **This information, coupled with indication of a possible on-going decline in numbers of molting harlequin ducks in the western sound, suggest that the harlequin duck has not recovered from the effects of the oil spill.**

Recent Trustee Council-sponsored studies give insight into prospects for recovery of harlequin ducks. Although some harlequin ducks make major seasonal movements, they exhibit high site fidelity to summer breeding sites and to molting and wintering sites during nonbreeding seasons. Strong site fidelity may limit population recovery by immigration, but a genetic analysis of harlequin ducks indicates that the spill-area population is homogeneous (i.e., very similar). Taken together, these data are consistent with a low rate of dispersal, perhaps at the subadult stage, or a rapid expansion of the population in recent geological time. To the extent that there is subadult dispersal from adjacent expanding populations, such dispersal would enhance recovery. It is likely, however, that recovery will largely depend on recruitment and survival from within injured populations. This recovery may be compromised if exposure to lingering hydrocarbons reduces fitness and survival of harlequin ducks

The Trustee Council has made a major investment in harlequin ducks, studying the possibility of on-going oil-related effects, gaining knowledge that will benefit long-term management and conservation, and protecting nesting and overwintering habitats. Harlequin ducks nest along anadromous fish streams, typically under forest cover and at higher elevations. Some of the more than 280 anadromous fish streams protected with the support of the Trustee Council provide nesting habitat for harlequin ducks. Molting and overwintering habitats are protected along the more than 1,200 miles of marine shorelines acquired through the habitat protection program. As a result, the terrestrial portion of the habitat base for harlequin ducks in the spill area is now significantly more secure.

Recovery Objective

Harlequin ducks will have recovered when breeding- and nonbreeding-season densities return to prespill levels. An increasing population and decreasing indications of exposure to hydrocarbons in oiled parts of Prince William Sound will indicate that recovery is underway.

Photo courtesy U.S. Fish and Wildlife Service

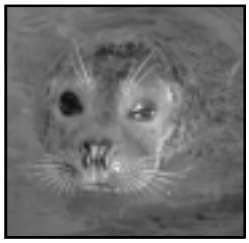
Harlequin Duck

Harbor Seals

Injury and Recovery

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 habitats, 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. 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.

In a declining population deaths exceed births, and harbor seals in both oiled and unoiled parts of Prince William Sound have continued to decline since the spill. **For the period 1989-1997, the average estimated annual rate of decline was about 5 percent, and for that reason harbor seals continue to be considered "not recovered."** Environmental changes in the late 1970s may have reduced the amount or quality of prey resources, including such forage fishes as Pacific herring and capelin, available to harbor seals in the northern Gulf of Alaska ecosystem. These changes may have been responsible for or contributed to the initial prespill harbor seal decline, and the ecosystem may now support fewer seals than it did prior to the late 1970s. Recent studies, however, indicate that the seals in the sound, especially pups and yearlings, are in very good condition and do not show evidence of nutritional stress. On-going sources of mortality include killer whale predation, subsistence hunting, and commercial fishery interactions (e.g., drowning in nets). Satellite tagging studies sponsored by the Trustee Council indicate that harbor seals in the sound are largely resident throughout the year, suggesting that recovery must come largely through recruitment and survival within injured populations.



Harbor Seal

Harbor seals have been a major focus of research sponsored by the Trustee Council since the oil spill. This research includes documentation of population trends in the field, improved statistical techniques for the analysis of aerial survey data, and exploration of possible sources of mortality and lack of recovery in the population, including health and diet. One study quantified normal blood chemistry values for several hundred seals; this database serves as a valuable tool for evaluating the health status of other seals. Starting in 1998, several projects exploring blood chemistry and other health parameters in relation to diet are being carried out at the Alaska SeaLife Center.

Harbor seals have long been a key subsistence resource in the oil-spill area. Subsistence hunting is affected by the declining seal population, and fewer opportunities to hunt seals have changed the diets of subsistence users who traditionally relied on these marine mammals. With partial support from the Trustee Council, the Alaska Native Harbor Seal Commission is working to involve Native hunters in research on and management of harbor seals. Alaska Native subsistence hunters have been helpful by providing seal researchers with measurements and hard-to-obtain tissue samples from harvested seals.

Recovery Objective

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

Intertidal Communities

Injury and Recovery

Portions of 1,300 miles of coastline were oiled by the spill in Prince William Sound, on the Kenai and Alaska peninsulas, and in the Kodiak Archipelago. Both the oil and intensive clean-up activities had significant impacts on the flora and fauna of the intertidal zone, the area of beach between low and high tides. Intertidal communities are intrinsically important and are resources for subsistence users, sea and river otters, and a variety of birds, including black oystercatchers, harlequin ducks, and pigeon guillemots.

Initial impacts to intertidal organisms occurred at all tidal levels and in all types of habitats throughout the oil-spill area. Many species of algae and invertebrates were less abundant at oiled sites than at unoiled reference sites. Some, more opportunistic species, including a small species of barnacle, oligochaete worms, and filamentous brown algae, colonized shores affected by the oil spill and clean-up activities. The abundance and reproductive potential of the common seaweed, *Fucus gardneri* (known as rockweed or popweed), also was reduced following the spill.

In the lower and middle intertidal zones on oiled rocky shores, algal coverage and invertebrate abundances had returned by 1991 to coverages and abundances similar to those observed in unoiled areas. However, large fluctuations in the algal coverage took place through 1997 in the oiled areas. This pattern is consistent with continued instability due to the original spill impact and the subsequent cleanup.

On the sheltered, bedrock shores that are common in Prince William Sound, full recovery of *Fucus* is crucial for the recovery of intertidal communities at these sites, since many invertebrate organisms depend on the cover provided by this seaweed. ***Fucus* has not yet fully recovered in the upper intertidal zone on shores subjected to direct sunlight, but in many locations, re-**

covery of intertidal communities has 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. In studies of the effects of cleanup activities on beaches, invertebrate molluscs and annelid worms on oiled and washed beaches were still much less abundant than on comparable unoiled beaches through 1997.

Beyond describing the effects of the oil spill and cleanup operations, the Trustee Council's restoration program has benefited intertidal communities in several respects. Although most tidelands in the spill area are already in state ownership, Trustee Council funds enabled the protection of sedge and mudflat habitats on the Homer Spit and enhanced protection of and access to rocky intertidal habitats at Kachemak Bay and at Lowell Point near Seward. Research and monitoring sponsored by the Trustee Council have greatly expanded knowledge of the distribution and ecology of north Pacific intertidal organisms, such as sea stars, and have provided models for statistically powerful sampling designs that can be incorporated into future injury assessments.

Recovery Objective

Intertidal communities will have recovered when community composition on oiled shorelines is similar to that which would have prevailed in the absence of the spill. Indications of recovery are the reestablishment of important species, such as *Fucus* at sheltered rocky sites, the convergence in community composition and organism abundance on oiled and unoiled shorelines, and the provision of adequate, uncontaminated food supplies for top predators in intertidal and nearshore habitats.

Kittlitz's Murrelets

Injury and Recovery

The Kittlitz's murrelet is found only in Alaska and portions of the Russian Far East. A large fraction of the world population, which may number only a few tens of thousands, breeds in Prince William Sound. The Kenai Peninsula coast and Kachemak Bay are also important concentration areas for this species. Very little is known about Kittlitz's murrelets, but they are known to associate closely with tidewater glaciers and nest on scree slopes and similar sites on the ground.

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. One published estimate places direct mortality of Kittlitz's murrelets from the oil spill as high as 1,000-2,000 individuals, which would represent a substantial fraction of the world population.

Because so little is known about this species, the Trustee Council funded an exploratory study on the ecology and distribution of the Kittlitiz's murrelet in Prince William Sound starting in 1996. Final results from this project are not yet available, but preliminary data confirm this species' affinity for tidewater glaciers in the four bays studied in the northern and northwestern parts of the sound. It also appears that reproductive output in 1996 and 1997 was extremely low or absent, and some Kittlitz's murrelets were apparently paired with marbled murrelets. There appear to be about 1,200-1,400 Kittlitz's murrelets during summer in the four bays studied in northern and northwestern sound. Other, more extensive marine bird boat surveys suggest a sound-wide summer population of at least 3,400 murrelets. These estimates are consistent with what is believed to be a small Alaskan and world population.

The population data, indications of low reproductive success, and affinity to tidewater glaciers (of which the lower elevation glaciers are receding rapidly) are reasons for concern about the long-term conservation of Kittlitz's murrelets. **Specifically with reference to the effects of the oil spill, however, the original extent of the injury and its recovery status are still unknown and may never be resolved.**

Recovery Objective

No recovery objective can be identified for Kittlitz's murrelet at this time.

Killer Whales

Injury and Recovery

More than 100 killer whales in six "resident" pods regularly use Prince William Sound as part of their ranges. Other whales in "transient" groups are observed in the sound less frequently. There has been particular concern in the sound about the resident AB pod, which numbered 36 animals prior to the spill. Fourteen whales disappeared from this pod in 1989 and 1990, during which time no young were recruited into the population. During the period 1992-94, four calves were added to the pod, but five additional adults were lost and presumed dead. During the most recent period, 1996-98, fives calves were recruited and only two adults were lost—a net gain of three individuals since 1992. If the calves born since 1992 survive and if additional calves are added to the pod over the next two or more years, the requirements for recovery will have been satisfied. **Pending evidence of sustained recruitment or at least stability, the kill whale is still considered to be not recovering.**

The original link between the AB pod losses and the oil spill was circumstantial. The rate of disappearance and likely mortality of killer whales in this well-studied pod in Prince William Sound following the spill far exceeded rates observed for other pods in British Columbia and Puget Sound over the last 20 years. In addition to the effects of the oil spill, there had been concern about the possible shooting of killer whales due to conflicts with long-line fisheries prior to the oil spill. There are no recent indications of such conflicts.

Overall numbers within the major resident killer whale pods in Prince William Sound are at or exceed prespill levels, even though the AB pod may or may not regain its former size. There is concern, however, that a decline in resightings of individuals within the AT1 group of transient killer whales has accelerated following the oil spill. Since 1990 and 1991, 10 individuals have been missing from the AT group and are now almost certainly dead. During that same period there has been no recruitment of calves into this group of transients. Transient killer whales largely prey on marine mammals, and there has been a 60 percent decline in the harbor seal population in the sound over the last two decades. Changes in the availability of such an important prey species could influence killer whale distribution and reproduction.

Trustee Council-sponsored research on contaminants in killer whales in Prince William Sound indicates that some whales are carrying high concentrations of PCBs, DDT, and DDT metabolites in their blubber. The presence of such contaminants is not related to the oil spill. Contaminants are significantly higher in the mammal-eating transients than in the fish-eating residents, consistent with the fact that contaminants bioaccumulate—that is they are more concentrated at higher trophic levels. Concentrations are highest in first-born calves, indicating that contaminants are passed on by nursing females. The high concentrations of contaminants found in the transient whales, including those in the AT1 group, are comparable to those found to cause reproductive problems in other marine mammals, but there is no unequivocal evidence of a link between contaminants and poor reproduction in the AT1 group.

Other work sponsored by the Trustee Council includes a detailed genetic analysis that has shown definitively that resident and transient killer whales in Prince William Sound are genetically distinct. The Trustee Council also has sponsored development of acoustic techniques for identifying and monitoring killer whales. Data on sightings and movements of killer whales indicate that the area around Knight Island and passages to Knight Island are among the most heavily used parts of Prince William Sound by both resident and transient killer whales. Use of the outer Kenai coast, including Resurrection Bay, appears to be increasing.

Recovery Objective

Killer whales in the AB pod will have recovered when the number of individuals in the pod is stable or increasing relative to the trends of other major resident pods in Prince William Sound.

Photo by Craig Matkin

Killer Whale

Marbled Murrelets

Injury and Recovery

The northern Gulf of Alaska, including Prince William Sound, is a key area of concentration in the distribution of marbled murrelets. The marbled murrelet is federally listed as a threatened species in Washington, Oregon, and California; it also is listed as threatened in British Columbia.

The marbled murrelet population in Prince William Sound had declined before the oil spill. The causes of the prespill decline are not known for certain, but environmental changes in the late 1970s probably reduced the availability or quality of prey resources. There is, nonetheless, clear evidence that oil caused injury to marbled murrelets in the 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. Many more murrelets probably were killed by the oil than were found, perhaps as much as 7 percent of the spill area population.

The recovery of the marbled murrelet population in Prince William Sound is assessed primarily through standard marine bird boat surveys. Based on a recent analysis of data from boat surveys carried out in July for most years from 1989-1998, densities of marbled murrelets increased substantially in oiled parts of the sound during 1990-1993, but declined again in 1996 and 1998. Densities of murrelets in unoiled parts of the sound also declined in 1996 and 1998, so the reason for the recent declines in both oiled and unoiled areas is probably due to some factor other than the oil spill.

The Trustee Council's recovery objective requires a stable or increasing population for marbled murrelets; stable or increasing productivity would indicate that recovery is underway. The marbled murrelet population is not now stable nor increasing, but the increase in oiled areas from 1990-1993 is a positive sign. In addition, marbled murrelet productivity, as measured by surveys of adults and juveniles on the water in Prince William Sound, appears to be within normal bounds. **On these bases, it appears that the marbled murrelet is at least recovering from the effects of the oil spill.**

Marbled murrelets have been a major focus of the Trustee Council's restoration program, including both habitat protection and research and monitoring activities. Marbled murrelets are known to nest in large, mossy trees within stands of old-growth forest. Following the oil spill, Trustee Council researchers identified specific habitat types and areas within the spill zone that are especially valuable to nesting murrelets. Much of the 600,000 acres of habitat protected with Trustee Council funds is forested, including significant habitat that is suitable for and used by nesting murrelets (for example, on Afognak Island).

In the area of research and monitoring, the Trustee Council's Alaska Predator Ecosystem Experiment (APEX) project is investigating the relationship between marbled murrelet declines and the availability and abundance of forage fish, such as Pacific herring, sand lance, and capelin. It appears that there is a direct correlation between the availability of forage fish and production of young murrelets, based on the presence of juvenile murrelets on the water in Prince William Sound. Historical trawl data analyzed as part of this project supported a decision by the North Pacific Fishery Management Council to limit bycatch of forage fish in commercial fisheries and to preclude the startup of fisheries targeting forage fish (not including herring).

Recovery Objective

Marbled murrelets will have recovered when their populations are stable or increasing. Stable or increasing productivity will be an indication that recovery is underway.

Mussels

Injury and Recovery

Mussels are an important prey species in the nearshore ecosystem throughout the spill area and are locally important for subsistence. Beds of mussels provide physical stability and habitat for other organisms in the intertidal zone and were purposely left alone during *Exxon Valdez* cleanup operations.

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. The biological significance of mussel beds that are still oiled is not known precisely, but they are potential pathways of oil contamination for local populations of harlequin ducks, black oystercatchers, river otters, and sea otters, all of which feed to some extent on mussels and other prey in and around mussel beds and which were injured by the oil spill. The Trustee Council's Nearshore Vertebrate Predator project has evidence of possible hydrocarbon exposure in sea otters, river otters, harlequin ducks, and Barrow's goldeneyes in oiled parts of Prince William Sound through 1996 or 1997, but the pathway of such exposure has not been established.

About 30 mussel beds in Prince William Sound still contained *Exxon Valdez* oil residue when last sampled in 1995. Twelve of these beds had been cleaned on an experimental basis in 1993 and 1994. In 1995, oil hydrocarbon concentrations in mussels at half the treated beds were lower than would have been expected if the beds had not been cleaned. In 1996, however, limited sampling indicated that several of the cleaned beds had been recontaminated from surrounding or underlying oil residue.

Mussel beds along the outer Kenai Peninsula coast, the Alaska Peninsula, and Kodiak Archipelago were surveyed for the presence of oil in 1992, 1993, and 1995. In 1995, hydrocarbon concentrations in mussels

and sediments at these Gulf of Alaska sites were generally lower than for sites in Prince William Sound, but at some sites substantial concentrations persist.

While several sites in Prince William Sound still contained high concentrations of oil in 1995, over half the sites surveyed demonstrated significant natural declines that suggest background concentrations should be reached in the next few years. On this basis, mussels are considered to be recovering. Oil contamination in mussels, however, will likely persist for many years at certain sites that are well protected from wave action or where oil penetrated deeply into underlying sediments.

In 1999, a series of oiled mussel beds will be inspected and monitored to track the recovery of this resource. Comparison of mussel beds cleaned in 1994 to beds that were not cleaned should provide valuable information for planning responses to future oil spills.

Recovery Objective

Mussels will have recovered when concentrations of oil in the mussels and in the sediments below mussel beds reach background levels, do not contaminate their predators, and do not affect subsistence uses.

Pacific Herring

Injury and Recovery

Pacific herring spawned in intertidal and subtidal habitats in Prince William Sound shortly after the oil spill. A significant portion of these spawning habitats as well as herring staging areas in the sound were contaminated by oil. Field studies conducted in 1989 and 1990 documented increased rates of egg mortality and larval deformities in oiled versus unoiled areas. Subsequent laboratory studies confirm that these effects can be caused by exposure to Exxon Valdez oil, but the significance of these injuries at a population level is not known.

The 1988 prespill year-class of Pacific herring was very strong in Prince William Sound, and, as a result, the estimated peak biomass of spawning adults in 1992 was very high. Despite the large spawning biomass in 1992, the population exhibited a density-dependent reduction in size, and in 1993 there was an unprecedented crash of the adult herring population. A viral disease and fungus were the probable immediate agents of mortality, but such other factors as competition for food may have reduced herring fitness and survival. Laboratory investigations since the population crash have shown that exposure to very low concentrations of *Exxon Valdez* oil can compromise the immune systems of adult herring and lead to expression of the viral disease. The extent to which the exposure to oil contributed to the 1993 disease outbreak is uncertain.

Numbers of spawning herring in Prince William Sound remained depressed through the 1995 season. In 1997 and 1998 the spawning biomass was about double that of 1994, the season following the crash, and there were limited commercial harvests for herring in the sound. , The increased biomasses in 1997 and 1998 are signs that recovery has begun. Unfortunately, the population has yet to recruit a highly successful year-class, which is fundamental to recovery of this species. **Thus, a full recovery has not been achieved, and the Pacific herring can only be considered to be recovering.**

Because the Pacific herring is extremely important ecologically and commercially and for subsistence users, the Trustee Council has made a major investment in restoration projects that benefit herring. In the area of habitat protection, Trustee Council funds have acquired more than 1,200 miles of upland shorelines, some of which will help protect water quality in areas used by spawning herring. Research sponsored by the Trustee Council also has identified bays that are important as herring nursery and overwintering areas, and this information will be useful to natural resource managers for decisions about siting facilities or planning responses to future oil spills.

The Trustee Council's Sound Ecosystem Assessment has resulted in new understanding of the importance of body condition in determining overwintering survival of herring and in the influences of the Gulf of Alaska in herring productivity within Prince William Sound. Techniques for improving stock and spawning biomass assessments through spawn deposition surveys and hydroacoustic and aerial surveys also have been supported by the Trustee Council. Ongoing research on herring disease in relation to commercial fishing practices, such as the enclosed "pound" fisheries, have direct implications for management of the herring fishery. Improvements in knowledge about the biology and ecology of herring and in assessment and management tools will enhance conservation and management of this species over the long term.

Recovery Objective

Pacific herring will have recovered when the next highly successful year class is recruited into the fishery and when other indicators of population health are sustained within normal bounds in Prince William Sound.

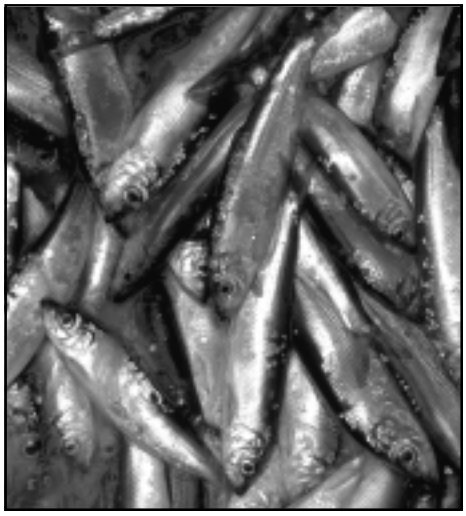


Photo by Roy Corral

Pacific Herring

Pigeon Guillemots

Injury and Recovery

Although pigeon guillemots are widely distributed in the north Pacific region, nowhere do they occur in large concentrations. Because guillemots feed in shallow, nearshore waters, the guillemots and the fish on which they prey are vulnerable to oil pollution.

Like the marbled murrelet, there is evidence that the pigeon guillemot population in Prince William Sound declined before the oil spill. The causes of the prespill decline are not known for certain, but environmental changes in the late 1970s probably reduced the availability or quality of prey resources. There is, nonetheless, clear evidence that oil caused injury to the guillemot population in the sound. An estimated 10-15 percent of the spill-area population died immediately following the spill. Boat-based surveys of marine birds before (1984-85) and after the oil spill indicated that the guillemot population declined throughout the oiled portion of the sound. **These same surveys indicate that numbers of guillemots remain depressed along oiled shorelines in the sound through 1998, and for this reason the pigeon guillemot is still considered to have not recovered from the effects of the oil spill.**

The Trustee Council's Alaska Predator Ecosystem Experiment (APEX) project is investigating the possible link between pigeon guillemot declines and the availability of high-quality forage fish, such as Pacific herring and sand lance. This work has revealed a strong connection between the availability of certain prey fishes, especially sand lance, and guillemot chick growth rates, fledging weights, and nesting population size. Historical trawl data analyzed as part of this project supported a decision by the North Pacific Fishery Management Council to limit bycatch of forage fish in commercial fisheries and to preclude the startup of fisheries targeting forage fish (not including herring).

The Nearshore Vertebrate Predator (NVP) project, also sponsored by the Trustee Council, addresses the possibility that exposure to oil is limiting the guillemot's recovery. Preliminary biochemical data do not indicate that guillemot chicks are being exposed to hydrocarbons.

Pigeon guillemots nest in rock crevices and under tree roots at the tops of rocky cliffs and steep slopes. They have benefited greatly from the habitat protection program, including the acquisition of more than 1,200 miles of marine shoreline. In addition, introduced foxes were eliminated from two of the Shumagin Islands (Simeonof and Chernabura) in the southwestern part of the spill area. Pigeon guillemots were present in low densities on both islands, but in higher densities on nearby fox-free islands. Although the nesting birds have not been surveyed since the foxes were removed in 1995, the elimination of this introduced predator should result in a large increase in the population of nesting guillemots.

Recovery Objective

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

Pink Salmon

Injury and Recovery

Certain features of the life history of pink salmon made this species highly vulnerable to damage from the oil spill. As much as 75 percent of wild pink salmon in Prince William Sound spawn in the intertidal portions of streams, where embryos deposited in the gravel could be chronically exposed to hydrocarbon contamination in the water column or leaching from 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 could have been exposed to oil as they swam through oiled waters and fed along oiled beaches. Trustee Council-sponsored studies have documented two primary types of injury due to the exposure of these early life stages: First, growth rates in both wild and hatchery-reared juvenile pink salmon from oiled parts of the sound were reduced. Second, there was increased egg mortality in oiled versus unoiled streams.

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. 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. The decade preceding the oil spill was a time of very high productivity for pink salmon in the sound, and, given the tremendous natural variation in adult returns, it is impractical to measure directly the extent to which wild salmon returns since 1989 were influenced by the oil spill. Based on intensive studies, including mathematical models, carried out following the spill, wild adult pink salmon returns to the sound's Southwest District in 1991 and 1992 were most likely reduced by a total of 11 percent.

Reduced juvenile growth rates in Prince William Sound occurred only in the 1989 season, but higher egg mortality persisted in oiled compared to unoiled streams through 1993. No statistically significant differences in egg mortalities in oiled and unoiled streams were detected in 1994 through 1996, but in 1997 there was again a difference. It is not clear whether the 1997 difference was due to the effects of lingering weathered oil, perhaps newly exposed by storm-related disturbance of adjacent beaches, or due to other factors. Patches of weathered oil still persist in or near intertidal spawning habitats in a few of the streams used by pink salmon in southwestern Prince William Sound. It is possible that patches of oil may be exposed as winter storms shift stream beds back and forth and result in local episodes of increased pink salmon egg mortality. The duration, scale, and number of any such events now would be limited in com-

parison to the situation that existed in the southwestern sound in 1989-1993. Therefore, the biological impact of exposure to any such lingering oil is unlikely to limit pink salmon populations, assuming there are no drastic negative changes in the quality of freshwater habitats and ocean rearing conditions.

Since the Trustee Council's recovery objective specifically requires a sequence of two years each of odd- and even-year runs without differences in egg mortality, this recovery objective clearly has not been met. **Thus, the Trustee Council continues to find that pink salmon are recovering from the effects of the oil spill, but that full recovery has not been achieved.**

The Trustee Council has made a major investment in studying the effects of the oil spill on pink salmon and in improving conservation and management of wild stocks in Prince William Sound. Studies on the effects of oil on pink salmon have led to new insights about how oil can affect salmon, especially in regard to the toxicity of even very small concentrations of weathered oil on early life stages. This information will be useful in evaluating water quality standards for oil in water and in contingency planning for future oil spills.

The Trustee Council has sponsored several projects directed at improved management of pink salmon. One of the most beneficial projects sponsored by the Trustee Council was development and implementation of a thermal mass marking project in Prince William Sound. This project, which is now being sustained by the Alaska Department of Fish and Game and the Prince William Sound Aquaculture Association, puts a unique mark on the otoliths (ear bone) of hatchery-reared fry released in the sound. Technicians can readily identify these fish when they are caught as returning adults. This information is used for in-season adjustments of harvests (times and areas) to better protect wild stocks and to more fully utilize hatchery stocks when doing so does not jeopardize wild stocks of pink salmon. Another project sponsored by the Trustee Council characterized the genetic stock structure of pink salmon in the sound. The results of this project will improve confidence that management actions are adequately protecting the genetic diversity of small wild stocks.

Throughout Alaska there is increasing recognition of the importance of changes in marine ecosystems on the growth and survival of salmon. The Trustee Council has funded the Sound Ecosystem Assessment (SEA) project to explore oceanographic and ecological factors that influence production of pink salmon and Pacific herring in Prince William Sound. These factors include such things as the timing of spring plankton blooms and changes in circulation patterns that link the sound to the Gulf of Alaska. These natural factors are likely to have the greatest influence on year-to-year returns in both wild and hatchery stocks of pink salmon. A final report from the SEA Project is due at the end of FY 1999.

Pink salmon have been major beneficiaries of the Trustee Council's habitat protection program. The more than 600,000 acres of land protected through the Trustee Council program include 280 streams with spawning and rearing habitat for salmon. Wild populations of pink salmon have been enhanced by creating or providing access to additional spawning habitat, such as the Port Dick spawning channel on the outer Kenai coast. This project is expected to result in production of additional pink salmon available for commercial harvest each year.

Recovery Objective

Pink salmon will have recovered when population indicators, such as growth and survival, are within normal bounds and there are no statistically significant differences in egg mortalities in oiled and unoiled streams for two years each of odd- and even-year runs in Prince William Sound.

River Otters

Injury and Recovery

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 Prince William Sound, including biochemical alterations, reduced diversity in prey species, reduced body size (length-weight), and increased home-range size. Because there were few prespill data, it is not certain that these differences are the result of the oil spill. Although some of the differences (e.g., in blood values) persisted through 1996, there were few differences documented in 1997 and 1998. **Thus, there are no indications of possible lingering injury from the oil spill, and the Trustee Council's recovery objective has been met.**

The Trustee Council's habitat protection program and research and monitoring projects have benefited spill-area river otters. More than 1,200 miles of marine shoreline and more than 280 streams used by anadromous fish streams have been protected; much of this area provides high-value habitat for river otters.

Through the Nearshore Vertebrate Predator project and other studies, much information has been gathered that will improve long-term conservation and management of river otters. These breakthroughs include development of a new method for live-trapping otters, which will improve the ability of wildlife managers to estimate population sizes for this elusive species, and new insights in the recycling of aquatic nutrients into forest ecosystems at otter latrine sites, which has important implications from a conservation standpoint. In addition, work in progress at the Alaska SeaLife Center on the blood chemistry of river otters in relation to small doses of oil will aid interpretation of biochemical tests for exposure from oil and other contaminants.

Recovery Objective

The river otter will have recovered when biochemical indices 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.

Rockfish

Injury and Recovery

Very little is known about rockfish populations (of several species) in the northern Gulf of Alaska. A small number of dead adult rockfish was recovered following the oil spill, and autopsies of five specimens indicated that oil ingestion was the cause of death. Analysis of other rockfish showed exposure to hydrocarbons and probable sublethal effects. In addition, closures to salmon fisheries apparently had the effect of increasing fishing pressures on rockfish, which, in turn, may have adversely affected local rockfish populations. **However, the original extent of injury and the current recovery status of this species are unknown.**

Because little is known about rockfish abundance and species composition in the spill area and because rockfish are harvested commercially, even basic information about these species could provide a basis for improved management or, at least, the identification of priorities for more targeted research. Accordingly, starting in FY 1998, the Trustee Council sponsored a multi-year study of genetic stock structure in black, dusky, and yelloweye rockfish throughout the spill area and the adjacent Gulf of Alaska. No results from this work are currently available.

Recovery Objective

No recovery objective can be identified.

Sea Otters

Injury and Recovery

By the late 1800s, sea otters had been eliminated from most of their historical range in Alaska due to excessive harvesting by Russian and American fur traders. Surveys of sea otters in the 1970s and 1980s, however, indicated a healthy and expanding population in most of Alaska, including Prince William Sound. Today the only harvests of sea otters are for subsistence purposes.

About 1,000 sea otter carcasses were recovered following the spill, and additional animals probably died but were not recovered. In 1990 and 1991, higher-than-expected proportions of prime-age adult sea otters were found dead in western Prince William Sound, and there was evidence of higher mortality of recently weaned juveniles in oiled areas. By 1992-93, overwintering mortality rates for juveniles had decreased, but were still higher in oiled than in unoiled parts of the sound.

Based on both aerial and boat surveys conducted in western Prince William Sound, there is statistically significant evidence of a population increase following the oil spill (1993-98). Observations by local residents bear out this general increase. However, within the most heavily oiled bays in the western sound, such as those on northern Knight Island, the aerial surveys indicate that recovery may not be complete.

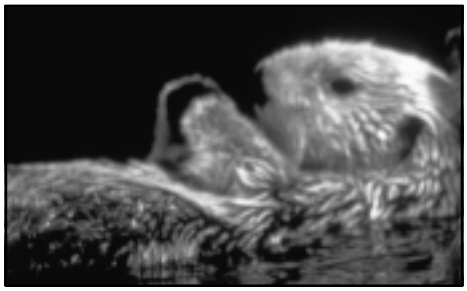


Photo by Robert Angell

Sea Otter

The Trustee Council's Nearshore Vertebrate Predator project, which was started in 1995, is addressing the lack of recovery in sea otters in the heavily oiled bays of western Prince William Sound. The lack of recovery may reflect the extended time required for population growth for a long-lived mammal with a low reproductive rate, but it also could reflect the effects of continuing exposure to hydrocarbons or a combination of both factors. Through 1997, researchers have continued to find biochemical evidence of oil exposure in sea otters on northern Knight Island. Biochemical samples from 1998 are now being analyzed. An additional hypothesis is that food supplies are limiting recovery, but preliminary evidence does not fully support this idea.

It is clear that sea otter recovery is underway for much of the spill-area, with the exception of populations at the most heavily oiled bays in western Prince William Sound. Researchers sponsored by the Trustee Council continue to explore hypotheses for lack of recovery at these sites.

Sea otters have benefited from many aspects of the Trustee Council's program. Sea otters are found along many miles of the more than 1,200 miles of marine shoreline that has been protected through the habitat protection program. Results of research and monitoring projects have also been valuable. For example, an aerial survey protocol is now being used more widely to monitor sea otter populations, and an improved and validated technique for aging sea otters using their teeth will aid biologists and veterinarians wherever sea otters are found. Another example is new information on age-specific reproductive rates, which is crucial for understanding the effects of subsistence harvests on sea otters. These new techniques and insights will aid sea otter conservation and management over the long term.

Recovery Objective

Sea otters will have recovered when the population in oiled areas returns to its prespill abundance and distribution. An increasing population trend and normal reproduction and age structure in western Prince William Sound will indicate that recovery is underway.

SEDIMENTS

Injury and Recovery

Exxon Valdez oil penetrated deeply into cobble and boulder beaches that are common on shorelines throughout the spill area, especially in sheltered habitats. Cleaning and natural degradation removed much of the oil from the intertidal zone, but visually identifiable surface and subsurface oil persists at many locations.

The last comprehensive survey of shorelines in Prince William Sound, conducted in 1993, included 45 areas of shoreline known to have had the most significant oiling. The average location with surface oil residue, asphalt, or mousse was 160 m^2 in size. Based on that survey, it was estimated that heavy subsurface oil had decreased by 65 percent since 1991 and that surface oil had decreased by 50 percent over the same time period.

The shorelines of the outer Kenai and Alaska Peninsula coasts get more wave action than most shorelines within Prince William Sound. These Gulf of Alaska sites tended to be contaminated with oil in the form of mousse, which can persist for long periods in a largely unweathered state. Five of six index beaches on the gulf coast have a heavy boulder "armor," and were last visited in 1993 and 1994. At this time, surface and subsurface oil mousse persisted in a remarkably unweathered state in the armored beaches.

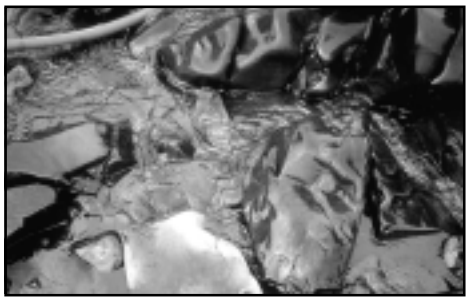
In 1995, a shoreline survey team visited 30 sites in the Kodiak Archipelago that had measurable or reported oiling in 1990 and 1991. The survey team found no oil or only trace amounts at these sites. The oiling in the Kodiak area is not persisting as it is at sites in Prince William Sound due to the higher energy unarmored beaches in the Kodiak area, the state of the oil when it came ashore, and the smaller concentrations of initial oiling relative to the sound.

Following the oil spill, chemical analyses of oil in subtidal sediments were conducted at a small number of index sites in Prince William Sound. At these sites, oil in subtidal sediments was mostly confined to the uppermost 20 meters water depths (below mean low tide), although elevated levels of hydrocarbon-degrading bacteria (associated with elevated hydrocarbons) were detected at depths of 40 and 100 meters in 1990 in Prince William Sound. By 1993, however, there was little evidence of *Exxon Valdez* oil and related elevated microbial activity at most index sites in Prince William Sound, except at those associated with sheltered beaches that were heavily oiled in 1989. These index sites—at Herring, Northwest, and Sleepy bays—are among the few sites at which substantial subtidal oiling is still known to occur.

Based on the information above, sediments are considered to be recovering. However, the presence of surface and 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. Concern on the part of Chenega Bay residents has been particularly strong. In 1997, with support from the Trustee Council, a project was carried out to use a chemical surfactant and other means to remove additional crude oil from 10,000 m^2 of beach on LaTouche and Evans islands in southwestern Prince William Sound. This effort was a partly successful, but a final evaluation of the results is not yet available.

Recovery Objective

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



Oily sediment in 1997

SOCKEYE SALMON

Injury and Recovery

Commercial salmon fishing was closed in Prince William Sound and in portions of Cook Inlet and near Kodiak in 1989 to avoid any possibility of contaminated salmon being sent to market. As a result, there were higher-than-desirable numbers (i.e., "overescapement") of spawning sockeye salmon entering the Kenai River and also Red and Akalura lakes on Kodiak Island. Research carried out following the spill demonstrated that initially these high escapements produced an overabundance of juvenile sockeye that then overgrazed the zoo-plankton, thus altering planktonic food webs in the nursery lakes. The result was lost sockeye production as shown by reduced growth rates during the freshwater part of the sockeye life history and declines in the returns of adults per spawning sockeye. Although sockeye freshwater growth tended to return to normal within two or three years following the overescapement, there are indications that these systems are less stable for several years after an initial overescapement event.

The negative effects of the 1989 overescapement on sockeye productivity, as measured by return per spawner, in the Kenai River watershed were readily apparent for returns from the brood years 1989-1992. Returns from the 1993-1995 brood years are not complete because some of these fish are still at sea, but returns to date show promise that management efforts have been successful in restoring the returns per spawner to normal levels. **The sockeye salmon of the Kenai River watershed are recovering from the effects of the 1989 overescapement.**

Production of zooplankton in both Red and Akalura lakes on Kodiak Island has rebounded from the effects of the overescapement at the time of the oil spill. By 1997, Red Lake had responded favorably in terms of smolt and adult production and was at or near prespill 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 have improved. This improvement is reflected in a strong adult escapement in 1998; a significant escapement of adults into Akalura Lake is also projected in 1999. **The sockeye populations of both Red and Akalura lakes are recovering from the effects of the 1989 overescapement.**

There also was concern about overescapement effects in 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 overescape-ment event.

The Trustee Council has made a major investment in the restoration and management of sockeye salmon, especially in the Kenai River system. Research sponsored by the Trustee Council has documented not only the effects of overescapement events (as described above), but also the mechanism by which the effects are manifested in glacial-lake systems. This work is helping fisheries managers better monitor and predict annual changes in sockeye fisheries. With support from the Trustee Council, genetic stock identification and hydroacoustic stock assessment techniques were developed and are being employed to improve in-season management of the Cook Inlet sockeye fisheries.

Sockeye salmon have benefited greatly from the Trustee Council's habitat protection program throughout the spill area. These acquisitions include streambank, lakeside, and watershed habitats along the Kenai and Moose rivers on the Kenai Peninsula, the Eshamy-Jackpot Bay area of Prince William Sound, the Red and Fraser lakes area on Kodiak Island, and Laura and Pauls lakes on Afognak Island. In addition to habitat acquisition, the Trustee Council sponsored a project to stabilize and restore degraded streambanks on public lands along the Kenai and Russian rivers. This project will restore spawning and rearing habitat important for salmon and enhance recreational fishing, which was a service injured by the oil spill.

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.

Subtidal Communities

Injury and Recovery

Shallow subtidal habitats of Prince William Sound, from the lower intertidal zone to depths of about 20 meters, typically have dense stands of kelp or eelgrass and contain numerous polychaete worms, snails, clams, sea urchins, and other invertebrate life. These subtidal communities provide shelter and food for an array of nearshore fishes, birds, and marine mammals.

Oil that was transported down to subtidal habitats, as well as subsequent cleanup activities, apparently caused changes in the abundance and species composition of plant and animal populations below lower tides. Different habitats, emphasizing eelgrass beds and adjacent areas of soft sediment, were compared at oiled and unoiled sites from 1990-1995. It is difficult to draw firm conclusions from this study, because it is hard to distinguish between natural site differences (e.g., percent sand and mud) and those differences actually resulting from the oil spill or cleanup.

Concentrations of hydrocarbons in subtidal sediments were significantly higher at oiled sites than at unoiled reference sites. These concentrations dropped sharply by 1991, but evidence of oil contamination due to *Exxon Valdez* oil persisted at some locations through 1995.

Biologically, negative effects of the oil were most evident for oil-sensitive species of amphipods, which were consistently less abundant at oiled than at unoiled sites. Reduced numbers of eelgrass shoots and flowers may have been due to increased turbidity associated with cleanup activities (e.g., boat traffic). Two species of sea stars and helmet crabs also were less abundant at oiled sites. Some invertebrates living in the sediment, including species in eight families of polychaete worms, two families of snails, and one family of mussels, were greater in numbers at oiled sites. These species are known to be stress-tolerant and probably benefited from the organic enrichment associated with oil. Some of the species that showed increased numbers also may have benefited from reduced competition or predation due to the effects of the spill.

By 1995, there was apparent recovery of most constituents of the eelgrass community and on this basis, subtidal communities can be considered to be recovering. Some amphipod and clam species continued to be less abundant at oiled sites, and there continued to be indications of enhanced numbers of stress-tolerant polychaetes and mussels. These sites have not been revisited since 1995.

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. Indications of recovery are the return of oil-sensitive species, such as amphipods, and the reduction of opportunistic species at oiled sites.

Human Services

Commerical Fishing
Passive Use
Recreation and Tourism
Subsistence

Commercial Fishing

Injury and Recovery

Commercial fishing is a service that was reduced through injury to commercial fish species (see individual resource accounts) and also through fishing closures. In 1989, closures affected fisheries in Prince William Sound, Cook Inlet, the outer Kenai coast, Kodiak, and Chignik. These closures harmed the livelihoods of persons who fish for a living.

Recovery is underway but not complete for three of the injured resources that are commercially fished — pink salmon, sockeye salmon, and Pacific herring; the recovery status of rockfish is unknown. No spill-related district-wide fishery closures related to oil contamination have been in effect since 1989. However, the Prince William Sound herring fishery was closed 1993-96 due to a disease outbreak that may be related to the oil spill, and was open only to limited commercial harvest in 1997 and 1998. **For these reasons, commercial fishing, as a lost or reduced service, is in the process of recovering from the effects of the oil spill, but full recovery has not been achieved.**

The period before the oil spill was a time of relative prosperity for many commercial fishermen. The years 1987-88 saw some of the highest ever per pound prices for salmon and increased capitalization of the fishery. Thus, fishermen's expectations for income in 1989 were very high, making the fishery closures and other spill effects even more disruptive.

For a variety of reasons, as discussed below, income disruptions continue today, as evidenced by changes in average earnings, ex-vessel prices, and limited entry permit values. For example, for the period 1981-97, fishermen's average earnings in the Prince William Sound salmon seine fishery peaked in 1987-88, dropped in 1989 to 1984-85 levels, rebounded in 1990, hit a new low in 1992-93 (runs in 1992-93 were the lowest in 15 years), and since have hovered somewhat below the 1989 level. Average harvests have varied widely during this period, with the

Photo by Roy Corral

Recovery is underway but not complete for three of the injured resources that are commercially fished — pink salmon, sockeye salmon, and Pacific herring.

three highest years being 1994, 1996, and 1997. Ex-vessel prices were highest in the period 1987-89, and have been below prices of the early 1980's ever since. Limited entry permit values in this fishery reached a peak in 1989-91, nearly double the value in any earlier year in this period, and have declined since to roughly 15 percent of their peak value. The number of permits fished, roughly 250 each year 1981-91, had declined to 114 in 1997.

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, IFQs, for halibut and sablefish), allocation changes (e.g., a reduction in the allocation of Cook Inlet sockeye salmon to commercial fishermen), and changes in processing capacity (closure of major processors in Cordova and Kenai and introduction of some smaller and more specialized processors).

Although a number of studies aimed at allocating financial impacts to the oil spill versus other factors have been carried out, the federal jury's compensatory award (as opposed to the $5 billion in punitive damages) in the private lawsuit against Exxon is the current legal determination of the liability and damages regarding commercial fishermen (including permit holders, fishing crew, spotter pilots, and vessel owners). The jury award, which is currently under appeal by Exxon, is less than the damage claimed by commercial fishermen and more than that acknowledged by Exxon. In brief, the jury determined that any financial effects on fishermen after 1989, with the exception of the salmon seine fishery in Prince William Sound in 1992-93 and the herring fishery in Prince William Sound in 1993, are not attributable to the spill. The jury considered damage claims for the period 1989-95, including claims related to size of harvest, fish prices, limited entry permit values, and vessel values.

Trustee Council scientists have documented some continuing biological injury to pink salmon, sockeye salmon, and herring (see individual resource accounts). It is not clear to what extent these continuing injuries might be affecting commercial fishing.

The Trustee Council has invested and continues to invest in projects to understand and restore commercially important fish species that were injured by the oil spill. These projects include enhancement work, such as fertilizing Coghill Lake to produce sockeye salmon and building structures in streams to increase habitat for coho salmon in Prince William Sound, increasing salmon production by reconstructing the fish ladder to pass pink and coho salmon at Little Waterfall Creek in the Kodiak area, and excavating Port Dick Creek on the Kenai Peninsula to reclaim spawning habitat for pink and chum salmon. Projects have also been funded to develop tools that have immediate benefit for fisheries management. Catch accounting tools as otolith mass marking of pink salmon and improved herring biomass estimates aid management in Prince William Sound, as do in-season genetic stock identification and marine sonar surveys for sockeye salmon in Cook Inlet. In addition, the Council continues to fund research projects, such as the Sound Ecosystem Assessment and genetic mapping which will enhance the ability to predict and manage fisheries over the long-term, and studies to determine how disease is affecting recovery of the herring population in Prince William Sound and what factors might trigger an outbreak.

In addition, the Trustee Council's habitat program has protected roughly 640,000 acres important for restoration, including over 300 streams valuable for salmon spawning and rearing and 1,400 miles of coastline. Researchers in the Pacific Northwest have concluded that depleted salmon populations cannot rebuild if any habitat that is critical during any of their life stages is seriously compromised. Sockeye salmon, too, have benefitted from the Council's habitat program, which has protected streambank, lakeside, and watershed habitats on the Kenai Peninsula, in Prince William Sound, and on Kodiak and Afognak islands. The Council has also provided funds to stabilize and restore degraded streambanks along the Kenai and Russian rivers.

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.

Passive Use

Injury and Recovery

Passive use encompasses nonuse values, such as the appreciation of the aesthetic and intrinsic values of undisturbed areas and the value derived from simply knowing that a resource exists. Injuries to passive use are tied to public perceptions of injured resources. **Because recovery of a number of injured resources is incomplete and in some cases has not begun, the Trustee Council considers passive use, as a lost or reduced service, to be recovering from the spill but not fully recovered.**

Immediately following the oil spill, the State of Alaska, using a contingent valuation approach, measured substantial losses of passive use values resulting from the spill. This approach involved surveying a sample of U.S. households to elicit how much people would be willing to pay in additional taxes to fund a program designed to prevent future spills. Prior to answering the survey questions, respondents were provided information about the spill's impact, including

the number of miles of shoreline oiled, an estimate of the number of birds, sea otters, and harbor seals killed, and the conclusion that few fish were harmed, as well as projections of when recovery would occur (typically three to five years).

In updating the status of passive uses ten years after the spill, the Trustee Council has chosen not to repeat the contingent valuation study, which was very expensive and time consuming. However, the key to recovery of passive use is knowing that restoration of injured resources has occurred. Toward this end, in the years since the settlement between Exxon Corporation and the state and federal governments, the Council has undertaken a comprehensive program to restore injured resources and has made a deliberate and consistent effort to inform the public about the status of restoration.

Photo by Roy Corral

The key to recovery of passive use is knowing that restoration of injured resources has occurred. Therefore, recovery of passive use is underway, but not complete.

The two key components of the Trustee Council's restoration effort are the research, monitoring, and general restoration program and the habitat protection and acquisition program. The research, monitoring, and restoration program, which is funded each year through the annual work plan, focuses mostly on knowledge and stewardship as the best tools for long-term health of the marine ecosystem. It also includes development of tools to benefit fisheries management and some direct enhancement activities, such as improving access to spawning habitat. Projects to monitor the status of injured resources, including resources such as killer whales for which no active restoration may be possible, are also funded through the annual work plan. The habitat protection program preserves habitat important to injured resources through the acquisition of land or interests in land. As of December 1998, the Council has protected over 640,000 acres of habitat, including more than 1,400 miles of coastline and over 300 streams valuable for salmon spawning and rearing. A summary of the Council's public information efforts follows.

The Trustee Council maintains a mailing list of roughly 3,000 people and organizations, both inside and outside of Alaska, to whom it sends the *Restoration Update*, its bimonthly newsletter; annual work plans, which describe the work underway in a particular year to restore the injured resources and services; the *Annual Status Report*, which reports to the public on the progress of restoration; updates to the Restoration Plan (1996, 1999); and notice of the Council's annual restoration workshop. The workshop, which provides another venue for reporting on the progress of restoration, is attended by all EVOS researchers and open to the news media and public.

In addition, from 1996 through early 1999 the Council aired a weekly radio series, "Alaska Coastal Currents", throughout the state. This two-minute program, produced by the Alaska Public Radio Network, was designed to communicate news of marine science and other restoration activities. A weekly newspaper column, based on the radio series, has been in print since June 1997.

Also in 1997, the Trustee Council established a web site (www.oilspill.state.ak.us), which offers detailed information about restoration efforts. A number of individual projects funded by the Council have their own web sites. The Council began publication of its Restoration Notebook series in 1997 as well. This series, which tells the story of injury and recovery from the spill of select injured species, is written by EVOS researchers. It is distributed free upon request, and is suitable for highschool age and older.

Another important means of informing the public are the written reports the Trustee Council requires for all restoration projects. These reports, which are peer reviewed by independent scientific peer reviewers, are available to the public through the Council's Oil Spill Public Information Center (now part of 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 NTIC (National Technical Information Services). ARLIS also houses books, videotapes, maps, and other materials related to the oil spill, a listing of which is available online at //library.ci.anchorage.ak.us/arlis.html. In addition, the Council supports researchers in publishing their project results in the peer-reviewed scientific literature, which expands their audience well beyond Alaska. More than 270 such papers have been published as of February 1999.

The 17-member Public Advisory Group (PAG), which was established in the civil settlement between Exxon Corporation and the state and federal governments, is an im-

portant means of keeping stakeholders and others informed of the progress of restoration. In addition to holding quarterly meetings with the Trustee Council staff, each year the PAG holds an open house in one or more communities in the spill area. Additional public meetings are held throughout the spill area each year by the Council and its staff. All meetings of the Council are widely advertised and opportunity for public comment, often via the teleconference network, is always provided. Press releases are issued following major actions of the Council.

In 1998-99, in preparation for the tenth anniversary of the spill, the Trustee Council has stepped up its efforts to inform the public about the status of restoration. A visual exhibit on restoration activities was produced for travel to spill area communities. Another exhibit is on display at the Alaska SeaLife Center in Seward. The Council's 1999 restoration workshop has been expanded to a major scientific symposium on what has been learned and accomplished in the restoration process. A 30-minute video has been produced for airing on public television in Alaska and for distribution to every school in the state.

In addition, a concerted effort by Trustee Council staff to interest national and international media in the 10th anniversary of the spill has resulted in numerous contacts. Major stories are expected in National Geographic Magazine, Alaska Geographic, Outside Magazine, Sports Afield and several other magazines in spring 1999. Several newspapers, including the Boston Globe, the Philadelphia Inquirer, and the Seattle Times, also have major stories in the works. A source reel prepared by the Council and containing three hours of footage related to restoration activities has been distributed, upon request, to a number of media outlets (ABC, CBS, CNN, and others) and documentary filmmakers.

Recovery Objective

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

Recreation and Tourism

Injury and Recovery

The oil spill disrupted use of the spill area for recreation and tourism. In the years since the spill, there has been a marked increase in the number of visitors to Alaska — from approximately 600,000 in the summer of 1989 to over 1.1 million in the summer of 1997 — and a similar increase in visitation to the spill area. For example, in 1997 the number of visitors to the Kenai Fjords National Park Visitor Center was nearly double what it was in 1989. In 1998, the number of visitors to the USFS Crooked Creek Visitor Information Center in Valdez was almost 50% greater than in 1989. From 1989 to 1997, the number of sportfishers increased by 65% in Prince William Sound, by 25% in the Kodiak Region, and by 15% in the Kenai Peninsula region.

Photo by Roy Corral

Wildlife tours in Kenai Fjords National Park

Photo by Robert Angell

Recreation includes sport fishing, sport hunting, camping, boating, hiking and other active outdoor pursuits.

However, 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, and this objective has not been met. **Therefore, the Council finds recreation to be recovering from the effects of the spill, but not fully recovered.**

Several resources important for wildlife viewing still are not recovered from the spill or their recovery is unknown, including killer whale, harbor seal, common loon, cormorant (three species), Kittlitz's murrelet, and pigeon guillemot. Others resources, including sea otter, common murre, black oystercatcher, and marbled murrelet are recovering. The bald eagle, another resource important for wildlife viewing, has recovered from the effects of the spill. (See individual resource accounts for more information on recovery status.)

Telephone interviews were conducted in early 1999 with key informants who recreated extensively in the oil spill area before the spill and currently. Nearly all of the key informants with experience in Prince William Sound continued to report diminished wildlife sightings in the sound, particularly in heavily oiled areas such as around Knight Island. They reported seeing significantly fewer seabirds, killer whales, sea lions, seals, and sea otters since the spill, but also reported observing increases in the number of seabirds in the last couple of years. Key informants with experience along the outer Kenai coast also reported diminished sightings of sea-

birds, seals, and sea lions. Changes in the amount of wildlife observed could be due to the oil spill or to other factors.

Sportfishing resources which are still injured by the spill or for which the recovery status is unknown are cutthroat trout, Dolly Varden, and rockfish. In 1991-93, in response to evidence of injury to cutthroat trout, sport harvests were temporarily restricted in Prince William Sound. A closure during the April 15-June 15 spawning season in the sound has been in effect since 1994; this closure reflects concern about the long-term conservation status of cutthroat trout, rather than specific spill-related concerns. The salmon species that were injured (pink and sockeye salmon) are recovering from the effects of the spill.

Harlequin ducks, which are hunted in the spill area, are still not recovered. The Alaska Board of Game restricted sport harvest of harlequin ducks in western Prince William Sound and Kenai Fjords in 1991. Those restrictions remain in place, but are currently under review and may be modified.

Trustee Council-sponsored surveys of oiled shorelines indicate that residual oil is still present on some beaches. The most recent survey in Prince William Sound (1993) found surface oil in 217 scattered locations along a total of 4.8 kilometers of shoreline and subsurface oil in 109 locations along a total of 7 kilometers of shoreline; sheening was apparent at many sites. The most recent survey of the Kenai outer coast and the coast of Katmai National Park (1994) found oil mousse persisting in a remarkably unweathered state on five moderately-to-heavily-oiled boulder-armored beaches. A survey of 30 oiled sites in the Kodiak Archipelago in 1995 found no oil or only trace amounts. The Katmai/Kenai Fjords shoreline survey will be repeated in the summer of 1999; the Prince William Sound survey likely will be repeated in 2001 or 2002.

Key informants telephoned in early 1999 indicated that some beaches in Prince William Sound, particularly in the western portion of the sound, continue to be avoided by some recreational users, particularly kayakers and campers, because of the presence of residual oil. Informants indicated that the possible presence of residual oil currently has no effect on recreational activities along the outer Kenai coast, the Kodiak Archipelago,and the Lake Clark and Katmai national park coastlines.

In 1997, the Trustee Council provided funding for the residents of Chenega Bay, working with the Department of Environmental Conservation, to use PES-51, a citrus-based chemical agent, to clean some of the most heavily-oiled sites near their village. One year later, preliminary analysis showed that the cleanup method was largely effective in removing the visible surface oil at treated sites, although considerable subsurface oil remains. NOAA's Auke Bay Lab found no biological injury due to the cleanup.

Recreational users have benefitted greatly from the Trustee Council's large parcel habitat acquisition program, which is opening more than 1,300 miles of shoreline and over 300 salmon streams to public use. Several smaller acquisitions have specific recreational significance, such as the Overlook Park tract near Homer and the Lowell Point parcel in Seward. In addition, in an effort to preserve the world-class fisheries on the Kenai River, the Council is in the process of protecting roughly 1,800 acres along the river and its watershed and has contributed nearly $2 million to riverbank restoration projects.

Recreation was also affected by changes in human use in response to the spill. For example, displacement of use from oiled areas to unoiled areas, particularly in the years immediately following the spill, increased management problems and facility use in unoiled areas. The State of Alaska dedicated over $10 million of its criminal settlement with Exxon to restoring recreational facilities and use in state parks in the spill area. Improvements include trails, cabins, boat launches, interpretive displays, and campsites. In addition, the Trustee Council has funded U.S. Forest Service development of a human use model for western Prince William Sound, which is intended to aid planning for and mitigation of human uses so that injured species continue to be protected. The model may also assist in planning for future recreation needs in the sound.

Recovery Objective

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

SUBSISTENCE

Injury and Recovery

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. Many families in other communities also rely on the subsistence resources of the spill area.

Household interviews conducted with subsistence users in communities throughout the spill area in 1989 indicated that subsistence harvests of fish and wildlife in most of the communities declined substantially following the spill. Key factors in the reduced harvests included reduced availability of fish and wildlife, concern about possible health effects of eating oiled fish and wildlife, and disruption of the traditional lifestyle due to cleanup and related activities. Household interviews were repeated each year 1990-1993 and again in 1998. By 1993, the estimated size of the subsistence harvest and participation in subsistence activities appeared to have returned to prespill levels in some communities, with the harvest rebounding first in the communities of the Alaska Peninsula, Kodiak Island, and the lower Kenai Peninsula and lagging behind a year or more in the Prince William Sound communities.

In 1998, interviews indicated that subsistence continues to recover from the effects of the oil spill, but has not fully recovered. The percentage of those interviewed who reported that subsistence uses

are lower than before the spill has declined. Concerns about food safety and effects on the traditional lifestyle have lessened. Concerns about resource availability and greater harvest effort remain, but harvest levels in all communities interviewed are at or approaching prespill levels. Subsistence harvests in 1998 varied among communities from 250-500 pounds per person usable weight, indicating continued strong dependence on subsistence resources.

Regarding resource availability, subsistence users continued to report scarcity of a number of important subsistence resources, including harbor seals, herring, clams, and crab. These observations are generally consistent with scientific studies funded by the Trustee Council that continue to find that some subsistence species (e.g., harbor seals, herring, clams) are not recovered from the effects of the spill. The Council continues to support research projects that seek to understand why these resources are not recovering and what, if anything, can be done to speed their recovery (see individual resource accounts).

Concerns about food safety and effects on the traditional lifestyle have lessened over the years. But, concerns about resource availability remain. Photo by Roy Corral

According to those interviewed, the 1998 increase in pounds harvested at a time of continued reduced resource availability reflects greater harvest effort (traveling farther, spending more time and money) than would have been required before the spill to achieve a similar harvest. It also reflects increased reliance on fish in the subsistence diet. For example, 1998 interviews in Chenega Bay indicated reductions in the per capita pounds harvested of marine mammals (from 140 pounds pre-spill to 15 pounds in 1998) and a corresponding increase in the per capita pounds harvested of salmon (from 70 pounds pre-spill to 225 pounds in 1998). In many communities, shellfish harvests have also declined significantly, for example in Nanwalek from 16 pounds pre-spill to 9 pounds in 1998. Increased fish harvests and decreased marine mammal and shellfish harvests occurred in most communities where interviews were conducted. The cultural and nutritional importance of each resource varies, and these changes in diet composition remain a serious concern to subsistence users.

The decline in shellfish consumption noted above reflects food safety concerns as well as reduced availability of shellfish. 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, because some shellfish can readily accumulate hydrocarbons, subsistence users have been advised not to eat shellfish from beaches where oil can be seen or smelled on the surface or subsurface. By 1998, a large majority of those interviewed expressed confidence about most foods except certain shellfish, such as clams, and concerns about the presence of PSP (paralytic shellfish poisoning) in clams outweighed concerns about lingering hydrocarbon contamination from the oil spill.

Interviews indicate that the increased fish consumption is attributable in part to enhancement projects funded by the Trustee Council, including a chinook remote release project near Chenega Bay, a coho remote release project near Tatitlek, stream enhancement efforts near Port Graham, and support of broodstock development at the Port Graham hatchery. In addition, the State of Alaska has used a portion of its funds from the criminal settlement with Exxon to sponsor a sockeye salmon enhancement project near Nanwalek. The Trustee Council's clam project, which is designed to restore clam populations near subsistence communities in lower Cook Inlet and Prince William Sound, is still in the trial phase. Clams have been planted on selected beaches, but are not yet available for harvest.

Subsistence users continue to emphasize that the value of subsistence cannot be measured in pounds alone. Harvest levels do not encompass the 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 1998, the number of subsistence users reporting a decline in the influence of elders in teaching subsistence skills and values had decreased and the number reporting that young adults are learning enough subsistence skills had increased. Also, the number reporting less sharing of subsistence resources, another integral aspect of subsis-

tence culture, had decreased. However, many of those interviewed continue to express concern about these elements of the traditional lifestyle, with more than 50 percent responding that the traditional way of life has not recovered since the spill.

To promote restoration of subsistence services, the Trustee Council has sponsored two Elders/Youth Conferences and production of two documentaries designed to transmit local knowledge of subsistence to the scientific community, resource managers, and decision makers. In addition, in 1993 the Council provided funds for construction of the Alutiiq Archaeological Repository in Kodiak and in 1999 is providing funds for an archaeological repository and local display facilities in the Prince William Sound/lower Cook Inlet region. The State of Alaska has used a portion of its Exxon criminal settlement funds for "spirit camps" in Prince William Sound and on Kodiak Island.

In the 1998 household interviews, a number of subsistence users commented that some of the current influences on subsistence may not be attributable to the oil spill. Factors such as demographic changes in village populations, ecosystem-wide changes such as ocean warming, increased competition for subsistence resources by other people (e.g., sport fishing charters) and 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.

Recovery Objective

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

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Photo by Kevin Hartwell

Opposite Page: Canoe Passage is one of more than 300 salmon streams protected through the Trustee Council's Habitat Protection Program. Habitat protection strongly benefits each of the human services, first by protecting the resources, but also by providing more public access for recreation, ensuring subsistence, and protecting spawning areas of wild salmon.

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