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OIL SPILL RESTORATION PLANNING OFFICE

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April 9, 1991

MEMORANDUM

SUBJECT: Release of Natural Resource Damage Summary

FROM: Sandy Rabinowitch, U.S. Dep't. of the Interior Sandy
for Linda Comerci, U.S. Environmental Protection Agency Ruth Yender

As you may be aware, the federal government released a report "Summary of Effects of the Exxon Valdez Oil Spill on Natural Resources and Archaeological Resources, March 1991", late Monday afternoon. Because of your interest in the oil spill and restoration, we are sending this copy to you. Please feel free to make additional copies and distribute them to others.

Although the Restoration Planning Work Group is not directly responsible for the damage studies, or this report, we will try to help you in any way that we can.

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UNITED STATES DISTRICT COURT
DISTRICT OF ALASKA

UNITED STATES OF AMERICA, Plaintiff, v. Exxon Corporation, Exxon Shipping Company, Alyeska Pipeline Service Company, Amerada Hess Pipeline Corporation, ARCO Pipe Line Company, Exxon Pipeline Company, Mobil Alaska Pipeline Company, Phillips Alaska Pipeline Corporation, BP Alaska Pipelines, Inc., Unocal Alaska Pipeline Company, and the T/V EXXON VALDEZ), in rem, Defendants.	CIVIL ACTION NO. A91-082

NOTICE OF LODGING OF UNITED STATES' SUMMARY OF EFFECTS OF EXXON VALDEZ OIL SPILL ON NATURAL RESOURCES

PLEASE TAKE NOTICE that the United States is lodging

with the Court the attached Summary of Effects of the EXXON VALDEZ Oil Spill on Natural Resources and Archaeological Resources (the "Summary"). The United States is lodging the Summary to assist the Court in evaluating the proposed Consent Decree lodged with the Court on March 13, 1991. The Summary is based on scientific studies conducted by the Departments of Agriculture and the Interior, the National Oceanic and Atmospheric Administration, and the Environmental Protection Agency to assess the injury to natural resources resulting from the oil spill.

The Summary is being lodged in advance of a motion to enter the proposed Consent Decree in order to give the Court additional time to consider the nature of injury to natural resources resulting from the oil spill.

Dated: April 8, 1991

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CERTIFICATE OF SERVICE

I certify that I caused to be served by mail the attached Notice of Lodging of United States' Summary of Effects of EXXON VALDEZ Oil Spill on Natural Resources and attached Summary of Effects of EXXON VALDEZ Oil Spill on Natural Resources and Archaeological Resources on

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SUMMARY OF EFFECTS OF THE EXXON VALDEZ OIL SPILL ON NATURAL RESOURCES AND ARCHAEOLOGICAL RESOURCES
March 1991

INTRODUCTION

The T/V Exxon Valdez ran aground on Bligh Reef in Prince William Sound on the night of March 23-24, 1989, spilling approximately 11 million gallons of North Slope crude oil, making this the largest oil spill in United States history. The oil spread through Prince William Sound, the Gulf of Alaska, and lower Cook Inlet. More than 1,200 miles of coastline were oiled, including portions of the Chugach National Forest, Alaska Maritime, Kodiak, and Alaska Peninsula/Becharof National Wildlife Refuges, Kenai Fjords National Park, Katmai National Park and Preserve, and Aniakchak National Monument and Preserve. Oil from the T/V Exxon Valdez impacted shorelines nearly 600 miles from Bligh Reef.

The magnitude of efforts of the state and federal governments, the public, and Exxon to contain and clean up the spill, rescue wildlife, and study the effects of the spill is unprecedented. Among those efforts are the state/federal natural resource damage assessment studies designed to measure injuries to natural resources including birds, mammals, fish and other wildlife, and marine and terrestrial habitats. These studies are intended to provide the information necessary for the Trustee agencies to manage and restore injured resources appropriately and to provide necessary documentation to enable the governments to present a claim for damages to the responsible parties. This summary briefly describes the area affected by the spill, the chronology of the spill, and the process developed to implement and manage the injury assessment studies. It focuses, however, on what has been learned over the past two years about the effects of this oil spill on natural resources.

DESCRIPTION OF THE AREA AFFECTED BY THE SPILL

Prince William Sound lies near the top of the Gulf of Alaska (see map), an 850 mile arc extending from the Aleutian Islands on the west to the islands of southeast Alaska. The gulf coast is remote, rugged, and scenic. Its maritime climate nourishes a lush, green landscape in the summer. The area is snow covered in the winter. Bears, whales, bald eagles, puffins, seals, sea lions, and sea otters are among the abundant wildlife of the area. Storms that cross the Gulf drop as much as 300 inches of rain and snow annually in the high coastal mountains. Glaciers descend from permanent ice fields capping these coastal mountain ranges, continuing to carve intricate fjords and send icebergs floating out to sea. These are the largest glaciers outside Antarctica and Greenland.

Prince William Sound is one of the largest relatively undeveloped marine ecosystems in the United States. It has one of the continent's largest tidal estuary systems. Prince William Sound has rich commercial herring and salmon fisheries. The open water of the Sound is about the size of Chesapeake Bay. Its many islands, bays, and fjords give it

more than 2,000 miles of shoreline. Prince William Sound is surrounded by land, most of which is part of Chugach National Forest.

To the southwest of Prince William Sound is the Kenai Peninsula, home of the Kenai Fjords National Park, various units of the Alaska Maritime National Wildlife Refuge, and, among others, the cities of Homer and Seward. Numerous seabird colonies are located along the coast of the Kenai Peninsula, including those most frequently visited by tourists in Alaska. Both Prince William Sound and the Kenai Peninsula are accessible by air, boat, and on a limited basis, by automobile from nearby Anchorage, Alaska's major population center. State ferries that run among the larger communities and many charter boats make it easy for people to visit the heart of the Gulf coast. In recent years, there has been a steady increase in the number of wilderness seekers, kayakers, cruise ship passengers, and other tourists visiting the area.

The Kenai Peninsula points southwest to Shelikof Strait and Kodiak Island. Shelikof Strait lies between Kodiak Island, on the south and the Alaska Peninsula on the north. Shelikof Strait is the source of a very productive commercial pollock fishery. The Kodiak National Wildlife Refuge is located on the Kodiak Archipelago and Katmai National Park and Preserve, Alaska Peninsula/Becharof National Wildlife Refuge, and Aniakchak National Monument and Preserve are located along the coast of the Alaska Peninsula. The Alaska Peninsula tapers, then scatters into the islands of the Aleutian chain.

CHRONOLOGY OF THE EXXON VALDEZ OIL SPILL

For the first three days of the spill, the weather was calm and the slick lengthened and widened amoeba-like and generally stayed in the vicinity of the grounded tanker and off the beaches. Even with these seemingly ideal circumstances for oil recovery, the amount of oil in the water completely overwhelmed efforts to contain and recover the oil. A major windstorm on March 27, 1989, pushed the oil in a southwesterly direction and oiled beaches on Little Smith, Naked, and Knight Islands. The oil continued to spread, contaminating islands, beaches, and bays in Prince William Sound. Four days into the spill, oil began to enter the Gulf of Alaska. The leading edge of the slick reached the Chiswell Islands off the coast of the Kenai Peninsula on April 2, 1989, and the major seabird nesting colonies on the Barren Islands on April 11, 1989, nineteen days into the spill. By May 18, 1989, oil had moved some 470 miles and had fouled shorelines of Prince William Sound, the Kenai Peninsula, the Kodiak Archipelago, and the Alaska Peninsula. Oil subsequently reached shorelines on the Alaska Peninsula nearly 600 miles from Bligh Reef.

During 1989, the response to contain and cleanup the spill and rescue oiled wildlife involved a massive effort. Skimmer ships were sent throughout the spill zone to vacuum oil from the water surface. Booms were positioned to keep oil from reaching important commercial salmon hatcheries in Prince William Sound. A fleet of fishing vessels, known as the "Mosquito Fleet," played an important role in protecting these hatcheries, in corralling oil to assist the skimmer ships, and in capturing oiled wildlife and

transporting these animals to rehabilitation centers. After oil contaminated shorelines, a beach cleanup program was activated. Various local committees, with community and government agency participation, provided recommendations to the U.S. Coast Guard about areas that should receive priority for cleanup. An army of workers cleaned shorelines, using techniques ranging from cleaning rocks by hand to high pressure hot water washing. Fertilizers, sometimes in a chemical base, were applied to some oiled shorelines to increase the activity of oil-metabolizing bacteria, in an experimental procedure known as bioremediation. When deteriorating weather brought an end to cleanup work in the fall of 1989, a great amount of oil remained on the shorelines. Although winter storms proved extremely effective in cleaning many beaches, spring shoreline surveys indicated that much work remained to be done in 1990. Crews operating from boats and helicopters cleaned oiled shorelines in Prince William Sound, along the Kenai and Alaska Peninsulas, and on the Kodiak Archipelago. Manual pick up of remaining oil was the principal method used during 1990, but bioremediation and relocation of oiled berms to the active surf zone were also used in some areas.[1] Another shoreline survey will be conducted during May 1991, to determine the need for additional cleanup work.

INJURY ASSESSMENT PROCESS

The Exxon Valdez oil spill occurred just prior to the most biologically active season of the year in southcentral Alaska. During the two month period after the spill, seaward migrations of salmon fry, major migrations of birds, and the primary reproductive period for most species of birds, mammals, fish, and marine invertebrate species took place. The organisms involved in these critical periods of their life cycles encountered the most concentrated, volatile, and potentially damaging forms of the spilled oil. As will be discussed in this summary, the oil affected different species differently. Whereas, for example, it directly killed large numbers of birds and sea otters that encountered oil on the water surface, it did not prohibit in and out migration and spawning of large schools of salmon and herring.

The state and federal Trustee agencies were forced to mobilize field studies rapidly with little time for planning. Through intensive efforts, studies were designed, administrative processes were accelerated, and 58 field studies were carried out. Additionally, technical services programs were organized to provide hydrocarbon analysis, histopathology, and mapping support for the field studies. Initial decisions on the types and scope of studies conducted were made by agency experts familiar with the resources and the environment. Even with the rapid deployment of studies, however, some opportunities to gather injury data were irretrievably lost during the early weeks of the spill.

A legal framework was subsequently established and studies were reviewed and modified according to their likelihood to document resource injury. Expert peer reviewers were retained and study plans used during 1989 underwent scientific review for possible

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[1] Exxon has represented that it has paid over $2.0 billion to conduct cleanup activities during 1989 and 1990.

modification in 1990. Some studies were discontinued or modified if they were unable to further document resource injury, and some new studies were initiated to fill identified information needs. Status reports prepared in January 1990, were used to guide the development of plans for the second year of studies. Thirty-nine studies and three technical services programs were continued in 1990. Scientific review was again used to plan for the upcoming 1991 field season, during which 29 studies and two technical services programs will be conducted.

This summary of the effects of the Exxon Valdez oil spill on natural resources is preliminary, as studies are still underway and available data are not fully analyzed and interpreted. However, the injuries to natural resources that have been documented to date are summarized herein. This summary also addresses studies that were discontinued. It should be noted that studies were discontinued for a variety of reasons, such as the determination that field work had been completed, that there was no practicable way to measure injury, or that no injury was documented. Even though some studies failed to identify injury and were discontinued, this does not necessarily mean that the resources were not affected by the spill. Certain injuries (if present), such as possible latent or sublethal effects on reproductive or other systems in animals, might not become fully evident for a number of years after the spill. At present there is no significant indication of long-term injury to resources other than those specifically noted below. Although studies indicate that there are continuing injuries to certain resources, natural recovery may also have begun. As petroleum hydrocarbons are broken down in the ecosystem, plant and animal communities begin to reestablish themselves. This recolonization has already been observed in some of the more lightly oiled areas. In the more heavily oiled areas, this natural recovery process is expected to take longer. As this natural recovery occurs, many of the birds and mammals that feed in these areas are expected to begin recovering.

MARINE MAMMALS

Following the spill, studies of humpback whales, Stellers sea lions, sea otters, harbor seals, and killer whales were started. The humpback whale and Stellers sea lion studies were discontinued following the 1990 field season. Humpback whale investigations were limited to photo identification of whales, estimations of reproductive success, and possible relocations of whales. It was not possible to take tissue samples for petroleum hydrocarbon analysis to document exposure. The study did not show direct oil spill mortalities or reproductive failures.

The sea lion study is being completed following the 1990 pup counts. Some tissue samples were analyzed for petroleum hydrocarbon concentrations, and although there was some indication of exposure to oil, it was difficult to determine what populations were affected because of the sea lions' active seasonal movements. Because of an ongoing pre-spill population decline and premature pupping of sea lions, it was not possible to distinguish post- from pre-spill population effects clearly.

Studies of killer whales, based on observations only (because tissue sampling was not an

option), have indicated that killer whales are missing from at least one and possibly two pods in Prince William Sound. Injuries to harbor seals and sea otters have been clearly indicated and studies of these species are continuing.

Sea Otters: The population of sea otters in Prince William Sound before the spill was estimated to have been as high as 10,000. The total sea otter population of the Gulf of Alaska was estimated to be at least 20,000. Statewide, the sea otter population is estimated at 150,000. Sea otters were particularly vulnerable to the spill. As the oil moved through Prince William Sound and the Gulf of Alaska, it covered areas used by large numbers of otters. When sea otters become contaminated by oil, their fur losses its insulating capabilities, leading to death from hypothermia. Sea otters also died as a result of ingestion of oil and perhaps inhalation of toxic aromatic compounds that evaporated from the slick shortly after the spill. The effects of oil were documented by surveys of wild populations; analysis of tissues for petroleum hydrocarbons and indicators of reduced health; by tracking sea otters outfitted with radio transmitters (including those released from rehabilitation centers); and estimating total mortality from the number of sea otters found on beaches. These studies concentrated on developing an estimate of sea otter mortality in Prince William Sound and along the Kenai Peninsula, the population most affected by the spill. During 1989, a total of 1,011 sea otter carcasses were recovered in the spill area, cataloged, and stored in evidence trailers. Of these, 876 were recovered dead from the field and 135 died in rehabilitation centers or other facilities. The total number of sea otters estimated to have been killed directly by the spill ranges from 3,500 to 5,500 animals throughout the spill area.

Initial results indicate significant differences in hematology and blood chemistry parameters between sea otters in oiled and unoiled areas. Greater variation was observed in DNA content of blood lymphocytes of sea otters from oiled areas, but sperm and testicular cells showed no indication of DNA damage resulting from oil exposure. It cannot yet be determined whether these differences affect sea otter health or survival. There are indications that sea otters continue to be exposed to petroleum hydrocarbons in oiled areas. Analysis of blood and fat samples collected from animals during 1990 found elevated concentrations of certain aromatic compounds in sea otters from heavily oiled areas and elevated concentrations of petroleum hydrocarbons continue to be documented in food items eaten by sea otters in oiled areas. Additionally, other damage assessment studies have documented a decreased abundance of mussels in oiled areas, a key prey species for sea otters.

Studies have documented continuing injury to sea otters. Normally, very few prime age sea otters (animals between 2 and 8 years old) die each year and most mortality occurs among very young and old age classes. The high number of prime age sea otter carcasses found during 1990 indicates that the pattern of sea otter mortality in heavily oiled areas continues to be abnormal. Results of boat surveys indicated continued declines in sea otter abundance within oiled habitats in Prince William Sound. Preliminary results indicate that pupping rates in oiled and unoiled areas are not significantly different. However, the first information available for the spring of 1991 shows higher yearling mortality rates in oiled areas than in unoiled areas. Studies of the survival and reproductive success of sea otters released from rehabilitation

centers indicate a high level of mortality of adult animals and significantly lower pupping rates than the pre-spill mortality and pupping rates in Prince William Sound. Of the 193 sea otters released from rehabilitation centers, 45 were fitted with radio transmitters. Sixteen of these animals are still alive, 13 are known to be dead, and 15 are missing. One radio transmitter is known to have failed.

Harbor Seals: There has been no census of harbor seals in Prince William Sound since the mid-1970s when the population was estimated at 3,000 to 5,000 animals. Since that time, the harbor seal population in Prince William Sound and the Gulf of Alaska has declined substantially. A population census of Prince William Sound is planned for the summer of 1991.

Two hundred harbor seals are estimated to have been killed by the spill. Only 19 seal carcasses were recovered following the spill, since seals sink when they die. Population changes were documented by summer and fall aerial surveys of known haulout areas. Toxicological and histopathological analyses were conducted to assess petroleum hydrocarbon accumulation and persistence and to determine toxic injuries to tissues.

Population surveys, which are reliable indicators of population trends, conducted in 1984 and 1988 indicated that harbor seal populations in Prince William Sound had declined prior to the spill, with similar declines in what were subsequently oiled and unoiled areas. From 1988 to 1990, however, the decline at oiled sites (35 percent) was significantly greater than at unoiled sites (13 percent).

Severe debilitating lesions were found in the thalamus of the brain of a heavily oiled seal collected in Herring Bay 36 days after the spill. Similar but milder lesions were found in five other seals collected three or more months after the spill. During 1989, oiled harbor seals behaved abnormally, being lethargic or unwary. Petroleum hydrocarbon concentrations in bile were 5 to 6 times higher in seals from oiled areas one year after the spill. This indicates that seals were still encountering oil in the environment, were metabolizing stored fat reserves that had elevated levels of petroleum hydrocarbons, or both.[2]

Killer Whales: Approximately 182 killer whales forming nine distinct family units or "pods" resided in Prince William Sound before the spill. This count is based on pre-spill documentation. These whales were studied intensively before the spill and their group composition and dynamics are well known. Damage assessment studies of killer whales involved extensive boat-based surveys in Prince William Sound and adjacent waters. Whales were photographed and the photographs were compared to the Alaskan

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[2]Harbor seals are taken in some Alaska villages for subsistence. The State of Alaska conducted a program, separate from the damage assessment program, to test subsistence foods potentially affected by the spill to insure that they were safe for human consumption. The State of Alaska determined that harbor seals in the affected area were safe for people to eat (Oil Spill Health Task Force, July-August 1990 Report and September-October 1990 Report. Alaska Department of Fish and Game, Division of Subsistence).

killer whale photographic database for the years 1977 to 1989 to determine changes in whale abundance, seasonal distribution, pod integrity, and mortality and natality rates.

The AB pod of 36 individual whales was sighted intact in September of 1988. When sighted on March 31, 1989, seven days after the spill, seven individuals were missing. These whales remain absent and six additional whales were missing from the AB pod in 1990. Several of the missing whales are females who left behind calves. It is unprecedented for females to abandon calves, therefore their prolonged absence implies that these adult females are dead. In addition, nine individuals from AT pod were missing in 1990. Explanations for the possible causes of death of these missing whales, including explanations apart from the effects of the spill, are being explored. Killer whale surveys will continue in 1991.

TERRESTRIAL MAMMALS

Studies were conducted on terrestrial mammals that may have been exposed to oil through foraging in intertidal habitats. These species included brown bear, mink, black bear, Sitka black-tailed deer, and river otters.

Brown bears are long-lived animals and forage seasonally in the intertidal and supratidal areas of the Alaska Peninsula and the Kodiak Archipelago. Preliminary analysis of brown bear fecal samples and some tissues show that some brown bears were exposed to petroleum hydrocarbons, but no conclusive injury has been documented. Radio-collared brown bears along the Katmai coast and at a control site on the Alaska Peninsula will continue to be monitored while the transmitters remain active.

Mink and other small mammals that are known to feed and spend part or all of their time in the intertidal zone are difficult to study. They are known to crawl off into burrows or the brush if sick or injured and carcasses are unlikely to be found. Also, information on pre-spill populations of these animals is minimal. Scientists developed a laboratory study to test reproductive effects of oil on ranch-bred mink, in which they were fed food mixed with small, non-lethal amounts of weathered oil. Although changes in reproductive rates or success were not documented, it was found that oil-contaminated food moved through the intestines of the animals at a more rapid rate than did clean food, possibly providing less nutrition to the animals.
No field studies were carried out for black bear due to the difficulty of finding, collaring, or otherwise investigating these animals in the dense underbrush in which they reside. However, a literature search confirmed that these animals do forage in the intertidal zone in the spill area.

The deer study found no evidence of injury based on intensive searches of beaches that revealed no mortality attributable to the spill. However, deer taken for purposes of testing for safety for human consumption (not part of the damage assessment process) found slightly elevated petroleum hydrocarbons in some tissues in deer (which feed on kelp in intertidal areas) but it was determined that the deer were safe to eat.

River Otters: A few river otter carcasses were found by cleanup workers. River otters forage in streams and shallow coastal habitats that were contaminated by the spill. Analysis of river otter bile indicated that petroleum hydrocarbons are being accumulated by this species. Studies of radio tagged animals in Prince William Sound showed that home ranges are larger, movements more erratic, and body weights are lower in oiled habitat. Field work is continuing in 1991 to further assess the status of this species, including analysis of blood samples to measure the health of these animals.

BIRDS

Among the most conspicuous effects of the Exxon Valdez oil spill was the injury to birds. Seabirds are particularly vulnerable to oil as they spend much of their time on the sea surface while foraging. Oiled plumage insulates poorly and loses buoyancy and birds die from hypothermia or drowning. Birds surviving initial acute exposure may then ingest oil by preening. Approximately 36,000 dead birds were recovered after the spill; at least 31,000 of these deaths were attributed to the effects of oil. In addition to the large number of murres, sea ducks, and bald eagles, carcasses of loons, cormorants, pigeon guillemots, grebes, murrelets, and other species were also recovered (see attached comprehensive list of bird carcasses logged into evidence trailers by September 25, 1989). Only a small proportion of the total number of birds estimated to have been killed were recovered, as many undoubtedly floated out to sea, sank, were scavenged, were trapped and hidden in masses of oil and were not visible, were buried under sand and gravel by wave actions, decomposed, or simply beached in an area where they were not found. Additionally, it is known that, in a number of cases, carcasses found shortly after the spill were not turned in to receiving stations. Preliminary analyses provided by computer models that account for some of these variables estimate that the total number of birds killed by the spill ranges from 260,000 to 580,000 with the best approximation that between 350,000 and 390,000 birds died. Following peer review, the model will be run again to provide a more refined estimate of total mortality.

Common and Thick-billed Murres: Murres are the third most abundant seabird in Alaska (after tufted puffins and black-legged kittiwakes). A total of approximately 1,400,000 murres reside in the Gulf of Alaska (Unimak Pass to the Canadian border in southeastern Alaska). The total population of murres in Alaska is approximately 12,000,000. The murre colonies on the Chiswell Islands are the most visited by tourists in Alaska. In 1989 and 1990 murres were the most heavily affected bird species. Murre colonies impacted by the spill lost 60 to 70 percent of breeding birds. Oil in Prince William Sound affected major wintering areas of murres and other species. As oil moved out of Prince William Sound and along the Kenai Peninsula and the Alaska Peninsula, it hit major seabird nesting areas such as the Chiswell and Barren Islands, as well as numerous smaller colonies. The oil hit these areas outside Prince William Sound at the same time that adult murres were congregating on the water near colonies in anticipation of the nesting season. Approximately 22,000 murre carcasses were recovered following the spill. Colony surveys indicate that an estimated minimum of 120,000 to 140,000 breeding adult murres in the major colonies that were surveyed were killed by the spill. Extrapolating this information to other known murre colonies hit by

the spill (but not specifically studied), the mortality of breeding adult murres is estimated to have been 172,000 to 198,000. However, area-wide, including wintering and non-breeding birds, the total mortality of murres is estimated to be about 300,000. Murres exhibit strong fidelity to traditional breeding sites and infrequently immigrate to new colonies.

Normally, murres breed in densely packed colonies on cliff faces. Each murre colony initiates egg laying almost simultaneously. This synchronized breeding behavior helps the birds repel predators such as gulls and ravens. In oiled areas, murre colonies have exhibited a much lower populations than before the spill, breeding is later than normal, and breeding synchrony has been disrupted. These structural and behavioral changes in colonies have caused complete reproductive failure during 1989 and 1990, and thus lost production of at least 215,000 chicks. Murre colonies in unoiled areas displayed none of these injuries and had normal productivity. Monitoring of reproductive success of the colonies will continue in 1991.

Bald Eagles: Of the estimated Alaskan bald eagle population of 30,000 birds (20,000 adults and 10,000 fledglings), an estimated 2,200 reside in Prince William Sound. One hundred forty-four (144) dead bald eagles were found following the spill. Although there is considerable uncertainty regarding the total mortality of bald eagles, it is estimated that several times this amount may have been killed by the initial spill. Approximately 90 percent of radio-tagged bald eagles that died during subsequent studies were not found on the beach but in the brush back from the beachfront. This suggests that most of the eagles that died in the spill would not have been found by surveys typically restricted to beach areas. To assess injuries to bald eagles, helicopter and fixed-wing surveys were flown to estimate populations and productivity. Radio transmitters were attached to bald eagles to estimate survival, distribution, and exposure to oiled areas. Bald eagles in Prince William Sound were most intensively studied. Productivity surveys in 1989 indicate a failure rate of approximately 85 percent for nests on moderately or heavily oiled beaches compared to 55 percent on unoiled or lightly oiled beaches. Bald eagles have a delayed sexual maturity and have a relatively long life span under normal circumstances. Consequently, although reproduction apparently rebounded to more normal levels in 1990, population impacts as a result of poor productivity of nestlings and the death of hundreds of adult eagles in 1989 may not be readily apparent for several years. Fewer bald eagles were sighted in 1990 than in 1989, however this change was within the expected error of the survey method. An additional survey will be conducted in 1991 to see if there is a downward population trend.

Sea Ducks: More than 2,000 sea duck carcasses were recovered after the spill, including more than 200 harlequin ducks. Studies concentrated on harlequins, goldeneyes, and scoters, species that use the intertidal and shallow subtidal habitats most heavily affected by the spill. Harlequins were most affected, consistent with the fact that they feed in the shallow water area of the intertidal zone. This is the only species of sea duck studied that both nests in the spill area and feeds in the shallow intertidal zone. All of these species feed on invertebrates such as mussels and are likely to continue to be exposed to petroleum hydrocarbons through their food. About 33 percent of the harlequins collected in the spill area had poor body condition and about 40 percent had

tissues contaminated with petroleum hydrocarbons. Preliminary surveys also indicate harlequins may have failed to reproduce in the spill zone in Prince William Sound during 1990. These injuries will be investigated further during 1991.

Other Birds: Surveys and studies indicate reduced numbers of black oystercatchers, pigeon guillemots, and marbled murrelets in oiled areas. Black oystercatchers and pigeon guillemots use inshore and intertidal areas for feeding and nesting. Reduced breeding success of black oystercatchers was documented in oiled areas, largely as a result of loss of chicks along oiled beaches. It is estimated that between 1,500 and 3,000 pigeon guillemots were killed by the spill, representing as much as 10 percent of the catalogued population in the Gulf of Alaska. This species is susceptible to continued exposure to petroleum hydrocarbons because it uses intertidal rocks and waters within 200 meters of shore. Petroleum hydrocarbons were found in eggs and tissue in 1989.

Marbled and Kittlitz's murrelets represented a high proportion of the dead birds recovered in oiled areas of Prince William Sound. The reduction in the number of murrelets observed in oiled areas during cleanup in 1989 and the return of many of these birds in 1990 suggest disturbance associated with cleanup activities affected these birds. The extent of injury to certain species, including loons, cormorants, and gulls will probably never be known because pre-spill information on numbers of these birds in the spill area are not available. Data on bird distribution and abundance data gathered during aerial and boat surveys remain to be fully analyzed and interpreted. Boat surveys will continue during 1991. Studies did not document injury to certain bird species such as Peale's peregrine falcons or songbirds.

FISH/SHELLFISH

No massive die-offs of adult fish were found following the spill, and adult salmon, for example, were evidently able to migrate to spawning areas after the spill. However, fish are most vulnerable to oil contamination during the early stages of their life cycles. Accordingly, most fish studies initially focused on this phase of fish life history. During 1991, scientists will begin to be able to assess affects on adult fish such as salmon that would have been exposed to oil as eggs or larvae. Species most often affected by the spill were those that inhabit and spawn in the intertidal zone (salmon) or in the shallow areas next to shore (herring and Dolly Varden).[3] Less than ten dead rockfish were found during the spill and their deaths were attributed to oil. Several species of coastal and offshore fish (pollock, halibut, sablefish, cod, yellowfin and flathead sole, and rockfish) show evidence over a large geographic area of continuing exposure to petroleum hydrocarbons in areas affected by the spill, but significant injury has not yet been documented. Exposure to petroleum hydrocarbons does not necessarily lead to

[3]The State of Alaska imposed the highest possible standards for commercial fishery openings and for processing plant inspections to insure that all commercially harvested salmon were free from contamination. Salmon subject to commercial harvest in the spill area were rigorously tested to insure that the catch was safe for human consumption.

injury, since many animals have the capability to physiologically "manage" the exposure with no resulting harm. In particular, salmon and other fish can metabolize petroleum hydrocarbons so that these contaminants are unlikely to be found in edible fish tissues. Indicators of exposure among fish include bile metabolites and mixed function oxidases. Since injuries from chronic exposure to oil may not manifest themselves for a number of years, it is premature to conclude that coastal and offshore species were not injured; therefore certain studies are continuing.

Pink Salmon: The full extent of short term injury to pink salmon cannot be assessed until after the 1991 run returns to spawn in the summer. Although the overall catch of pink salmon in Prince William Sound during 1990 was an all-time record (as predicted before the spill), this was primarily due to strong runs of hatchery-produced salmon. Salmon survival associated with the Armin F. Koerning hatchery, located in the middle of a heavily oiled area of the spill zone, was half that of Ester Hatchery, located outside the area of the spill. Wild production of pink salmon did not mirror the record production of hatchery fish.

Seventy-five percent of wild pink salmon spawn in the intertidal portion of streams in Prince William Sound. Wild stock salmon did not shift spawning habitat following the spill and deposited eggs in intertidal areas of oiled streams. Preliminary analyses indicate a 70 percent greater mortality of pink salmon eggs laid in the summer of 1989 and a 50 percent greater mortality in the summer of 1990 in oiled streams as compared to control streams. Larvae from heavily oiled streams showed gross morphological abnormalities, including club fins and curved spines. The pink salmon that returned to Prince William Sound in the summer of 1990 were exposed to oil as larvae as they swam under the slick, but not as eggs which were more directly exposed to oil than the larvae. Fish returning in 1991 will be the first that were exposed to oil as eggs. Eggs and larvae of wild populations continue to be exposed to oil in intertidal gravel in oiled areas.

Sockeye Salmon: Commercial harvest of sockeye salmon was curtailed in portions of Cook Inlet, Chignik, and Kodiak in 1989 because of the spill, resulting in an unusually high number of adults migrating to spawn in certain lake spawning systems (returning adults that arrive at the spawning areas are referred to as the "escapement"). Overly large spawning escapements may result in poor returns in future years by producing more juvenile salmon than can be supported by the nursery lake's productivity. Preliminary data indicate that overescapement degraded rearing habitat in lakes and that sockeye salmon survival and growth rates are lower than usual. Further study is needed before the extent of these injuries can be determined.

Dolly Varden and Cutthroat Trout: Prince William Sound is the northern extreme of the range of cutthroat trout. Both cutthroat trout and Dolly Varden use nearshore and estuarine habitat for feeding throughout their lives (in contrast to salmon which migrate out to sea). The highest concentrations of bile petroleum hydrocarbon metabolites in all fish sampled were found in Dolly Varden. Tagging studies have demonstrated that the annual mortality of adult Dolly Varden was 32 percent greater in oiled areas than in unoiled areas. The larger cutthroat trout showed similar levels of mortality in oiled and unoiled areas. Additionally, cutthroat trout growth rates were reduced in oiled areas.

Studies are continuing to measure impacts on populations of these popular sport fish species.

Pacific Herring: Populations of Pacific herring were spawning in shallow eelgrass and algal beds at the time of the spill. The effects of oil on egg survival, hatching success, larval development, and recruitment to the spawning population were studied. Study results show a large increase in the percentage of abnormal embryos and larvae in oiled areas of Prince William Sound during the 1989 reproductive season. Larvae in oiled areas also had a greater incidence of eye tumors. These effects continued but at somewhat lower rates in 1990. Results also showed greater egg mortality in oiled areas as compared to unoiled areas. Whether the adult population has been affected by these larval injuries will not be determined until the 1989 and 1990 cohorts return to spawn in 1992 and 1993.

COASTAL HABITAT

The coastal tidal zone, commonly known as the "intertidal zone," was the most severely contaminated habitat. Intertidal habitats are highly productive and biologically rich. They are particularly vulnerable to the grounding of oil, its persistence, and effects of associated clean-up activities. An interdisciplinary team with expertise in plant and systems ecology, marine biology, and statistical analysis, was established to conduct field studies to assess the effects of oil on intertidal ecosystems.

Supratidal: Results of studies in the Kodiak/Alaska Peninsula area suggest that oil in the supratidal habitat and beach cleanup disturbance decreased the productivity of grasses and other vegetation including beach rye grass, that help stabilize beach berms. In one instance, cleanup activities completely removed the vegetation. Increased production of supratidal vegetation was found in Prince William Sound in 1989. This finding corresponds with information from other oil spills. It is not known whether this increased production was a result of decreased browsing by terrestrial mammals or a fertilizer effect of the oil.

Intertidal: Natural populations of intertidal organisms were significantly reduced along heavily oiled shorelines such as Herring Bay. Densities of intertidal algae (Fucus), barnacles, limpets, amphipods, isopods, and marine worms were decreased. Although there were increased densities of mussels in oiled areas, they were significantly smaller than mussels in the unoiled areas and the total biomass of mussels was significantly lower. Intertidal organisms continue to be exposed to hydrocarbons from the more heavily oiled sediments. Petroleum hydrocarbon accumulation in filter feeding mussels experimentally placed in oiled areas indicate that oil remains available for uptake by other organisms. Initial findings also indicate that oiled surfaces retarded settlement by juvenile barnacles when compared to unoiled sites. In addition to direct mortality, the reproductive cycle of mussels at oiled sites in the lower Cook Inlet/Kenai Peninsula and Kodiak/Alaska Peninsula regions was delayed by several months.

Intertidal fishes were less abundant in oiled areas than in unoiled areas. In addition, gill

parasitism and respiration rates were significantly higher in fish from oiled sites compared to unoiled sites.

Fucus, the dominant intertidal plant, was severely affected by the oil and subsequent cleanup activities. The percentage of intertidal areas covered by Fucus was reduced following the spill and opportunistic plant species which characteristically flourish in disturbed areas were increased. The average size of Fucus was reduced, the number of reproductive sized plants greatly decreased, and the remaining plants of reproductive size decreased in reproductive potential due to fewer fertile receptacles per plant. There was also reduced recruitment of Fucus at oiled sites.

SUBTIDAL HABITATS

Spilled oil in some areas has migrated to and contaminated the seafloor at depths of up to 100 meters as contaminated sediments moved off beaches during winter storms and cleanup activities. There is evidence that petroleum hydrocarbons have been taken up by animals feeding on the ocean bottom. Petroleum hydrocarbon metabolites have been found in the bile of yellowfin sole, rock sole, rockfish, and pollock. Concentrations of petroleum hydrocarbon metabolites in the bile of yellowfin sole have not declined from 1989 to 1990. This contrasts with Dolly Varden which feed close to shore and where petroleum hydrocarbon metabolites in bile decreased in the same period. The effects of this exposure are still being studied. Many subtidal and intertidal species, particularly fish, have the capability of metabolizing and eliminating petroleum hydrocarbons from their bodies. Clams metabolize hydrocarbons very slowly and consequently accumulated them in high concentrations.

Contaminated clams and other invertebrates are a potential continuing source of petroleum hydrocarbons for sea otters and otherspecies that forage in the shallow subtidal zone. Samples from pollock, which feed in the water column, taken as far away as 500 mile from the wreck site on Bligh Reef, showed elevated petroleum hydrocarbon metabolite concentrations in their bile. This indicates that the water column or food supply was affected at great distances from the spill. Initial 1990 study results show a significant effect on benthic organisms associated with eelgrass beds. These are known to be highly productive habitats. The composition of benthic animal communities on soft-bottom habitats as deep as 40 meters were also significantly altered in oiled areas.

ARCHAEOLOGICAL AND SUBSISTENCE RESOURCES

The spill directly impacted archaeological sites and subsistence resources. Cleanup activities and the associated significant increases in human activity throughout the spill zone resulted in additional injuries to these resources.

Archaeological Resources: Archaeological sites along the shoreline were injured by the

spill. Review of spill response data revealed injuries from oil to a minimum of 26 archaeological sites. Among these are burial sites and home sites. Twenty-one (21) of these sites are on federally-owned land, with the remaining five on State of Alaska and private lands. Of the 21 sites on federal land, 10 are on national parks, six on national wildlife refuges, four within Chugach National Forest, and one on Bureau of Land Management land. While injury to these 26 sites was documented during cleanup, a spill-wide assessment of injuries to archaeological resources has yet to be completed. In addition to oil contamination, increased knowledge of the location of archaeological sites may put them at risk from looting. Loss of rye grass cover may threaten some sites. A comprehensive survey of injuries to archaeological resources on public lands throughout the spill zone will be conducted during 1991.

A study was conducted to determine impacts caused by oil contamination on radiocarbon dating of archaeological resources and to investigate the potential for cleaning artifacts and materials to allow such dating. Preliminary results indicate significant injury to the ability to contextually date artifacts and materials by Carbon 14 analysis. It also appears that these materials cannot be successfully "cleaned" to allow accurate dating.

Subsistence Resources: Surveys undertaken by state researchers before the spill and in 1990 indicated that subsistence harvesters in the area affected by the oil spill significantly reduced their use of subsistence resources after the spill, primarily because of their concerns about possible contamination of these resources. The oil spill disrupted the subsistence lifestyle of some communities that have historically relied upon these resources. Some communities virtually or entirely ceased subsistence harvests in 1989 and have only gradually begun to resume harvests, while other communities continued some reduced level of subsistence harvest in 1989 and thereafter. The attached report (Subsistence Use of Fish and Wildlife in 15 Alutiiq Villages after the Exxon Valdez Oil Spill) details these studies. Warnings were issued by the state in 1989 for people to avoid consumption of intertidal invertebrates (such as mussels and clams, which bioaccumulate petroleum hydrocarbons) found along shorelines contaminated by oil. After the spill, an oil spill health task force was formed, including the state and federal governments, subsistence users, and Exxon. This group helped oversee studies conducted by the state and others in conjunction with FDA and NOAA in 1989 and 1990, on subsistence food resources such as seals, deer, salmon, ducks, clams, and bottomfish. Based upon the test results these resources, with the exception of clams and mussels in certain oiled areas such as Windy Bay, were determined to be safe for human consumption.

CONCLUSION

The federal and state Trustee agencies have now concluded two field seasons of study and are currently preparing to begin a third year of studies to assess injuries to natural resources resulting from the Exxon Valdez oil spill. The information contained in this

summary is based upon the field work and data analysis conducted to date, and is preliminary. Many studies will likely need to continue for additional years before a full understanding of injuries is developed. For example, long-lived species such as bald eagles, murres, and sea otters, may not manifest some effects until a number of years have passed. For other species, such as herring and salmon that return to spawn years after hatching, it is necessary to wait for these key life history events to occur before one can determine the extent to which or if they have been injured. At present there is no indication of long-term injury for species other than those noted in this summary. Although two field seasons of study are complete, only a portion of the data gathered has been fully analyzed and interpreted. As studies and data analysis are completed, some of the information contained in this summary may need to be modified.

For the reasons given above, injury assessment studies will continue in 1991, and thereafter until the process is complete. The need to continue to understand the long-term effects of the spill will be accomplished through monitoring projects that will measure the natural recovery of resources injured by the spill as well as the effectiveness of restoration measures implemented by the Trustee agencies. The information gathered by the injury assessment studies, the restoration monitoring studies, and other studies will be used to develop and implement a restoration program that will accelerate the recovery of injured resources.

Restoration measures will begin in 1991 and are expected to become more comprehensive as the understanding of the effects of the spill improves and as experts and the public provide input on where restoration measures should be concentrated. Wherever possible, restoration will focus on those projects that will provide ecosystem-wide benefits, thereby benefitting a variety of species. These projects may include various initiatives to protect habitat; in other cases it may be necessary to conduct restoration programs that will primarily benefit a particular resource injured by the spill.

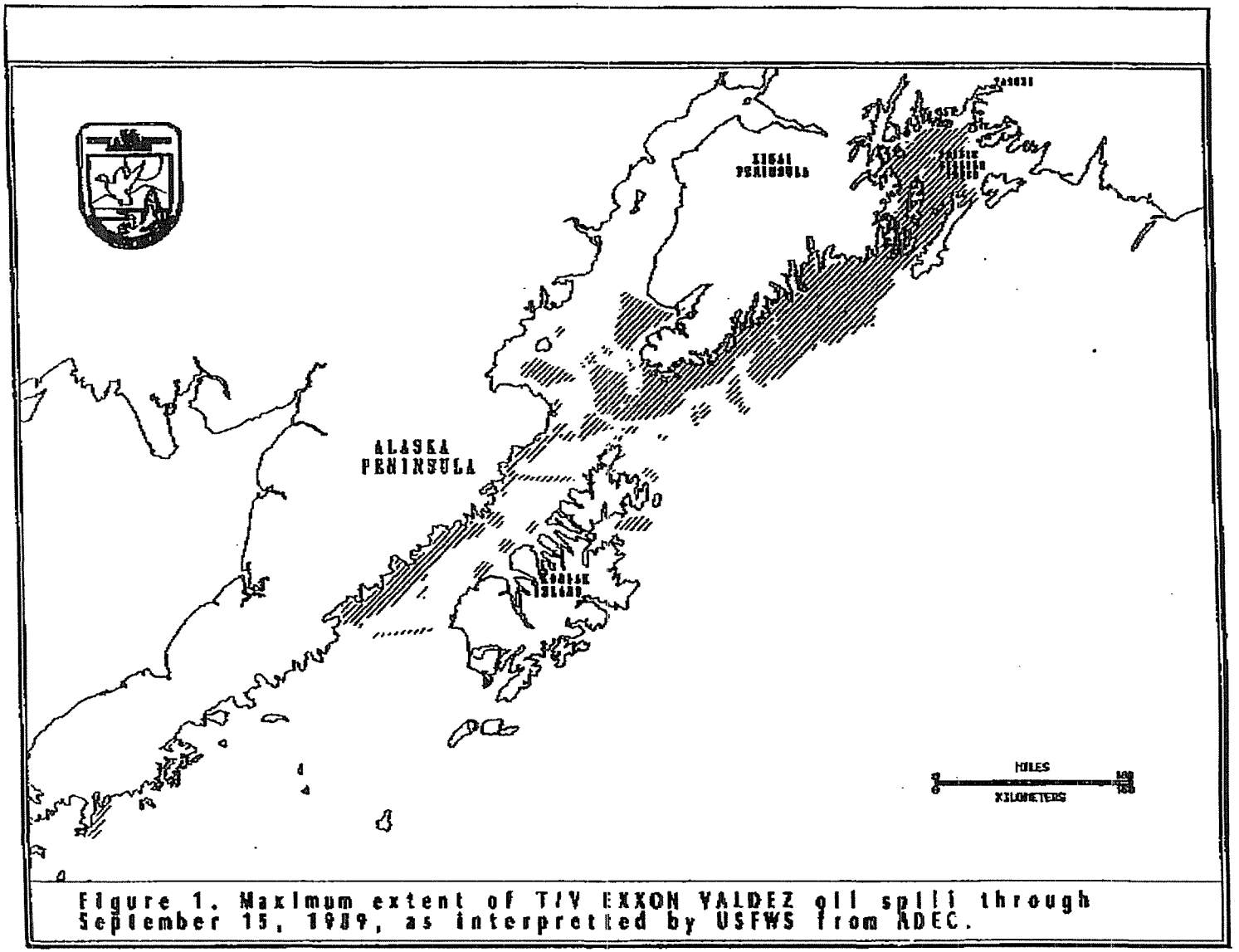

Figure 1. Maximum extent of T/V EXXON VALDEZ oil spill through September 15, 1989, as interpreted by USFWS from ADEC.

Table 1. Species composition and number of birds retrieved from oiled areas and processed at U.S. Fish and Wildlife receiving stations as of 25 September, 1989. (Cont'd)

Species	Total	Valdez	Seward	Homer	Kodiak
Unidentified alcid	173	24	0	15	134
Unidentified murre	8,851	21	775	2,101	5,954
Common Murre	10,428	399	523	1,353	8,153
Thick-billed Murre	669	16	142	73	438
Pigeon Guillemot	614	136	109	155	214
Unidentified murrelet	413	21	37	121	234
Marbled Murrelet	612	289	97	82	144
Kittlitz's Murrelet	67	23	19	21	4
Ancient Murrelet	311	3	40	73	195
Cassin's Auklet	48	0	36	2	10
Least Auklet	5	0	0	1	4
Parakeet Auklet	31	1	2	1	27
Rhinoceros Auklet	141	0	31	31	79
Unidentified puffin	46	0	7	4	35
Horned Puffin	139	0	32	13	94
Tufted Puffin	361	0	29	15	317
Bald Eagle	125	31	20	15	59
Unidentified raptor	7	1	3	2	1
Peregrine Falcon	2	0	0	0	2
Willow Ptarmigan	1	0	0	0	1
Unidentified owl	1	0	0	1	0
Great-horned Owl	3	0	0	3	0
Unidentified woodpecker	1	0	0	1	0
Cliff Swallow	3	0	3	0	0
Violet-green Swallow	1	0	1	0	0
Unidentified passerine	9	1	7	1	0
Stellar's Jay	1	1	0	0	0
Magpie	7	1	0	0	6
Common Raven	18	1	4	0	13
Northwestern Crow	34	6	3	3	22
American Robin	2	0	2	0	0
Varied Thrush	1	0	0	0	1
Hermit Thrush	1	0	1	0	0
Unidentified warbler	1	0	0	0	1
Yellow Warbler	3	0	3	0	0
Pine Grosbeak	1	0	0	0	1
Unidentified sparrow	15	0	10	2	3
Savannah Sparrow	1	0	1	0	0
Golden-crowned Sparrow	4	0	3	0	1
White-winged Crossbill	8	0	0	6	2

Table 1. Species composition and number of birds retrieved from oiled areas and processed at U.S. Fish and Wildlife receiving stations as of 25 September, 1989.

Species	Total	Valdez	Seward	Homer	Kodiak
Total	35,279	3,360	3,503	5,778	22,638
Unidentified bird	2,927	476	414	916	1,121
Unidentified loon	69	27	6	25	11
Common Loon	216	142	23	32	19
Yellow-billed Loon	87	72	5	3	7
Pacific Loon	18	8	5	0	5
Red-throated Loon	5	3	1	1	0
Unidentified grebe	65	27	8	11	19
Red-necked Grebe	120	79	22	12	7
Horned Grebe	277	233	15	22	7
Northern Fulmar	426	0	22	12	115
Unidentified shearwater	579	5	22	14	538
Sooty Shearwater	360	4	80	34	242
Short-tailed Shearwater	2,460	1	84	4	2,371
Unidentified petrel	69	2	24	14	29
Fork-tailed Storm-petrel	363	1	50	19	293
Leach's Storm-petrel	12	0	9	0	3
Unidentified cormorant	219	76	27	56	60
Double-crested Cormorant	38	19	10	0	9
Pelagic Cormorant	418	277	65	29	47
Red-faced Cormorant	161	90	29	9	33
Great Blue Heron	1	1	0	0	0
Unidentified swan	3	0	2	1	0
Emperor Goose	2	0	0	0	2
Canada Goose	1	0	0	1	0
Brant	3	0	1	2	0
Unidentified duck	30	4	6	20	0
Unidentified seaduck	112	63	2	11	36
Mallard	11	2	4	1	4
Northern Pintail	4	0	3	1	0
Green-winged Teal	5	0	5	0	0
Unidentified Scaup	4	1	3	0	0
Greater Scaup	27	2	21	4	0
Lesser Scaup	2	0	2	0	0
Unidentified Goldeneye	25	8	2	14	1
Common Goldeneye	6	3	0	2	1
Barrow's Goldeneye	33	19	9	4	1
Bufflehead	21	17	1	0	3
Oldsquaw	185	131	43	6	5

Table 1. Species composition and number of birds retrieved from oiled areas and processed at U.S. Fish and Wildlife receiving stations as of 25 September, 1989. (Cont'd)

Species	Total	Valdez	Seward	Homer	Kodiak
Harlequin Duck	213	148	10	35	20
Unidentified Eider	3	0	0	3	0
Stellar's Eider	4	4	0	0	0
Common Eider	17	5	0	2	10
King Eider	9	0	0	0	9
Unidentified Scoter	162	23	17	51	71
White-winged Scoter	342	164	13	137	28
Surf Scoter	175	45	28	9	6
Black Scoter	132	112	4	8	8
Ruddy Duck	1	0	1	0	0
Unidentified merganser	3	1	0	0	2
Common Merganser	2	2	0	0	0
Red-breasted Merganser	33	30	1	1	1
Sandhill Crane	2	1	1	0	0
Black Oystercatcher	9	2	2	0	5
Golden Plover	1	0	0	1	0
Unidentified sandpiper	11	1	5	1	4
Unidentified turnstone	1	0	0	0	1
Common Snipe	1	0	0	1	0
Semipalmated Sandpiper	1	0	1	0	0
Lesser Yellowlegs	2	0	0	2	0
Western Sandpiper	5	0	0	5	0
Baird's Sandpiper	1	0	0	0	1
Least Sandpiper	4	0	2	0	2
Surfbird	3	3	0	0	0
Short-billed Dowitcher	1	0	0	0	1
Red Phalarope	2	0	0	2	0
Red-necked Phalarope	7	1	3	0	3
Long-tailed Jaeger	1	0	0	0	1
Unidentified gull	99	6	34	39	20
Glaucous-winged Gull	555	33	188	28	213
Herring Gull	8	3	5	0	0
Mew Gull	33	0	3	3	27
Black-legged Kittiwake	1,225	8	214	74	929
Arctic Tern	3	1	1	0	1
Aleutian Tern	1	0	0	0	1