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# COMPREHENSIVE REVIEW AND CRITICAL SYNTHESIS OF THE LITERATURE ON RECOVERY OF ECOSYSTEMS FOLLOWING MAN-INDUCED AND NATURAL-PHENOMENA-RELATED DISTURBANCES: HARBOR SEALS AND KILLER WHALES

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**DRAFT REPORT**

to

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EXECUTIVE SUMMARY

Populations of most marine mammals have suffered large reductions, some to near extermination, by aboriginal and commercial harvests, incidental or indiscriminate killing, and epizootics during the past two centuries. Once direct killing by humans ended many of those populations increased at relatively high annual rates, varying from about 7-21% for pinnipeds to 2-12% for cetaceans. The causes for recent steady declines, following population recoveries, of northern fur seals, northern sea lions and harbor seals in the Bering Sea, Aleutian islands, and western Gulf of Alaska and southern elephant seals in most areas of the southern ocean remain unexplained.

Recent epizootics killed over 18,000 seals (mostly harbor seals) in European waters and several thousand, perhaps, in Lake Baikal in the Soviet Union, but no data are yet published to evaluate population responses following those reductions. Nonetheless, the historical occurrences of documented epizootics and the prevalence of antibodies to various viruses in seal populations today suggests that seals that survived the diseases quickly developed immunities and provided nuclei for population recovery.

Population responses of seals and sea lions in the Pacific to natural environmental disturbances (e.g., 1982/83 El Nino Southern Oscillation = ENSO) have recently been documented (Trillmich and Ono, eds. 1991). Data on their recoveries have not yet been published, but our studies (Stewart and Yochem, In Press; Stewart, In Press) have indicated only temporary demographic consequences. Historical, large-scale fluctuations in oceanographic conditions related to ENSOs may have influenced periodic fluctuations in seal abundance in the Antarctic (Testa et al. 1991); there is no evidence that such fluctuations have affected population persistence.

Overall, long-term population data for pinnipeds and cetaceans are similar in demonstrating the potential of these species for sustained high rates of population growth following population reduction, even to very low abundance. However, in those situations there is no reason to think that either breeding or foraging habitat was degraded or eliminated.

Fouling of pinnipeds and cetaceans by oil has evidently had insignificant effects on populations;

substantial mortality has never been observed, even following catastrophic spills (Tables 1 and 2). The effects of oiling on individuals varies depending on whether oil coated the body surface or was ingested, or whether aromatic hydrocarbons were inhaled. In most cases the results are based on casual observations, and systematic experiments have often been ambiguous (see St. Aubin 1990, and Geraci 1990 for reviews).

Wursig (1990) ranked cetacean vulnerability to oil based on five life history parameters. Species with small ranges, coastal/ice-dwelling/riverine habitats, limited diets, poor behavioral flexibility, and small or endangered population status were considered the most vulnerable. Those species with large ranges, oceanic habitat, diverse prey, adaptable behavior, and large population sizes were least vulnerable. For pinnipeds, the greatest impacts to health may be on stressed animals or on nursing or recently weaned pups. These animals are long-lived, however, and even the loss of an entire cohort would have insignificant long-term demographic effects (e.g., McLaren 1990). Prolonged inhalation of hydrocarbon vapors appears to pose the greatest risk to an animal's vitality. Yet, St. Aubin (1990) concluded that "for most pinnipeds, particularly in northern habitats, it is unlikely that petroleum vapors could become sufficiently concentrated to represent a threat. However, selected individuals within a given population may be particularly sensitive and thus...brief exposure to relatively low concentrations...might be fatal if combined with other stimuli eliciting a major adrenal response. Parasitic lung disease, a relatively common finding in pinnipids, would further complicate the effects of even mild irritation of respiratory tissues".

McLaren (1990) concluded that significant amounts of hydrocarbons would probably not be consumed by pinnipeds in their food because the prey are unlikely to accumulate residues; possible exceptions include bearded seals and walruses foraging in heavily contaminated benthic environments. Harbor seals, which feed primarily on benthic and epibenthic prey in many areas, may also be an exception. In any case ingestion of hydrocarbons and hydrocarbon residues is not thought to pose significant health risks to marine mammals (St. Aubin 1990, Geraci 1990). Of greater significance is the direct effects of oil fouling of benthic communities and the cascading effects on other parts of the food chain that depend on those communities for food (e.g., larvae). Pitcher (1980b) reported that the most important year-round prey for harbor seals near Tugidak island (near the EXXON Valdez Oil Spill area = EVOS) was octopus, a prey that is also an important dietary component for harbor seals in other areas. Loss of octopus populations in the EVOS area because of benthic oil fouling could depress or delay the recovery of harbor seal numbers there; recovery of octopus populations would likely be slow because of their limited dispersal abilities. If so, harbor seals would likely broaden their prey base or disperse to more productive coastal habitats. Killer whales consume a wide variety of prey, feeding mostly on fish but apparently switch to marine mammals when fish are less available (Braham and Dahlheim 1982). This flexible and varied foraging behavior should make them at low-risk for ingesting large amounts of hydrocarbons, unless they prey on marine mammals that have accumulated residues. Killer whales that were "resident" in the EVOS area and nearby region might also avoid that area in favor of more productive unaffected areas. Future research to assess actual population damage and recovery of harbor seals and killer whales following degradation of the EVOS area habitat should document the movement patterns of individual seals and whales with satellite or conventional telemetry and intensive photo-identification studies. Surveys should cover a larger area and be conducted during more seasons than previous research efforts, particularly for killer whales. Such studies should probably be conducted at several year intervals to permit long-term, cost-effective evaluation of population recovery; but careful attention should be given when designing the study to the statistical power of such an approach.

Because historical, pre-human intrusion abundance of harbor seals and killer whales is unknown in the EVOS area (or elsewhere for that matter), evaluation of when a population has recovered using abundance data (or an index of abundance) alone is not strictly possible. Therefore, some criteria (e.g., habitat occupation, an arbitrarily established, desired local population size, physical or physiological condition of individuals) of recovery need to be established.

## 1.0 INTRODUCTION

### 1.1 Background

On 24 March 1989, around 11 million gallons of North Slope crude oil spilled into Prince William Sound from the grounded oil tanker EXXON Valdez. About 60% of the oil was not recovered and drifted or was blown southwest along the Kenai Peninsula toward Shelikof Strait, resulting in the fouling of over 1200 miles of mainland and island coastline and an unknown area of ocean bottom. Resident populations of harbor seals and killer whales may have been affected during the spill by fouling of skin or pelage, inhalation of volatile, short-chain hydrocarbons, ingestion of oil, immediate destruction of prey resources and long-term food chain contamination.

Evidently, substantial numbers of harbor seals became oiled in the EVOS area. Some were likely exposed to toxic aromatic hydrocarbons in areas very near the spill source. Harbor seals are relatively abundant residents of Prince William Sound and the Gulf of Alaska. Little is known of their daily and seasonal hauling patterns, absolute abundance, movements, life history parameters and diet within the EVOS area but detailed information does exist for local populations elsewhere in species' broad distribution. Daily terrestrial abundance of harbor seals is greatest at mid-day (e.g., Stewart 1984; Yochem et al. 1987) or during daytime low tides (Schneider and Payne 1983, Terhune and Almon 1983); seasonal terrestrial abundance is greatest during the molt in spring or summer and least in winter. Terrestrial abundance at a large haulout area on Tugidak Island near the EVOS area declined substantially (about 85%) from 1976 through 1988 for unknown reasons; it may be relevant that large numbers of pups were harvested there from 1964 through 1972 (Pitcher 1990). The trend in Prince William Sound was presumably similar but there are no published data for that area. The decline at Tugidak Island contrasts with the steady increases in most other parts of the harbor seal's range during the past several decades (e.g., Harvey et al. 1990, Heide-Jorgensen and Harkonen 1988, Olesiuk et al. 1990, Stewart et al. 1988, Stewart et al. 1991).

Seasonal site-fidelity as well as short- and long-distance movements of harbor seals have been documented in some areas (e.g, Brown and Mate 1983, Pitcher and MacAllister 1981, Yochem et al. 1987); no comparable data are available for the EVOS-Prince William Sound area. Seasonal, sexual and age-class segregation has also been reported for some areas (e.g., Allen et al. 1988, Kovacs et al. 1990).

The diet of harbor seals is relatively broad with respect to spatial and temporal species composition, but benthic and epibenthic species generally predominate (e.g., Brown and Mate 1983, Harkonen 1987, Olesiuk et al. 1990, Payne and Selzer 1989, Pitcher 1980a, 1980b).

Leatherwood et al. (1990) documented a minimum of 221 killer whales in Prince William Sound in 1987, based on photo-identification of individuals. These whales belonged to nine "resident" and eight "transient" pods, as defined by Bigg (1982) and other researchers in British Columbia and Washington. Recent DNA research has supported the hypothesis that these pods are genetically distinct (Hoelzel and Dover 1991). The combined mortality rate for all ages and both sexes from 1984-86 was 1.9% in three pods, but 7.4% in another (AB pod). The latter pod has been interfering with the blackcod (Anoplopoma fimbrica) longline fishery since 1985 and bullet wounds have been observed on some of its members. Leatherwood et al. (1990) did not report an annual rate of population increase for killer whales but noted that 9 calves were born in 1986 and 1987. In British Columbia and Washington, where killer whales have been studied using the same techniques as Leatherwood et al. (1990), annual rates of increase ranged from 1.67 to 3.01 (Balcomb et al. 1982, Bigg 1982, Olesiuk et al. 1990) and annual mortality rates from 0.7% (adult females) to 2.81% (adult males).

The distribution of killer whales, unlike most other cetaceans, is not limited by water temperature or depth. They occur in deep pelagic waters and in coastal areas, along ice edges and in pack ice as well as in the tropics (Mitchell and Reeves 1988). Local movements and distribution appear to be largely dictated by distribution and availability of prey (Dahlheim 1981, Braham and Dahlheim 1982, Heimlich-Boran 1988). A partial list of prey items by geographic area was presented by Anon. (1982). Killer whales consume a variety of marine vertebrates and invertebrates, including fish, cephalopods, seabirds and mammals. There are differences in food habits between sympatric pods in some areas: resident pods in British Columbia and Washington consume mainly fish (especially salmon), whereas transients feed mostly on marine mammals (especially harbor seals; Felleman et al. 1991, Heimlich-Boran 1988).

Here we summarize, in the form of an annotated bibliography, published information on the population effects of oil spills on harbor seals and killer whales and other relevant pinnipeds and cetaceans throughout their ranges. We also summarize demographic information on the responses of pinniped and cetacean populations to other anthropogenic and natural disturbances and on rates and patterns of population recovery.

### 1.2 Objectives

The objectives were to review the published literature on population growth rates of harbor seals and killer whales, particularly in the Gulf of Alaska, and other relevant cetaceans and pinnipeds and summarize population responses of those species to anthropogenic (especially oil spills) and natural disturbances.

## 2.0 TECHNICAL APPROACH

### 2.1 Information retrieval and sources of data

Computerized literature searches were made through DIALOG (accessing BIOSIS, AQUATIC SCIENCES AND FISHERIES ABSTRACTS and OCEANIC ABSTRACTS) and MELVYL (accessing all University of California book and periodical holdings). Direct searches were made of current scientific literature at libraries at Scripps Institute of Oceanography, San Diego State University, UCLA, and UC Davis. Finally, our personal and Institute libraries were the most productive sources of information on pinniped and cetacean biology. The literature recoveries from these initial searches were used in a hierarchical way to provide additional key words for additional searches and additional reference lists of previously published literature.

3.0 Review of available information of recovery of marine mammal populations from anthropogenic and natural disturbances

3.1 Rate, duration, and degree of recovery following disturbance.

3.1.1 Pinnipeds

A. Harbor seals

In recent years, harbor seal populations have been increasing in most areas where commercial or subsistence harvesting is low or absent (e.g., Harvey et al. 1990, Heide-Jorgensen and Harkonen 1988, Olesiuk et al. 1990, Stewart et al. 1988, Stewart et al. 1991). Documented rates of population increase are relatively high, around 10-22 % per year. Most of the increases have occurred after bountied and indiscriminate killing and harvesting were outlawed. Degree of recovery is generally impossible to judge as pre-exploitation abundances are unknown. In a few other areas, however, populations have declined or fluctuated at low levels. In some cases chronic pollution is believed to be responsible for reproductive failures and depressed populations of harbor and other seals (Helle et al. 1976, Reijnders 1978, Zakharov and Yablokov 1990). There has also been a persistent decline in the western Gulf of Alaska around Tugidak Island (Pitcher 1990), and perhaps in Prince William Sound. Causal factors may include 1) degradation of habitat (reduction of prey resources, natural environmental changes, virulent pathogens, etc.) or 2) substantial undocumented mortaltity associated with commercial fishing operations or native subsistence harvest.

In 1988, an epizootic killed over 18,000 seals, mostly harbor seals in European waters. In Swedish and Danish waters of the Kattegat and Skagerak more than 5300 harbor seals died; the population had previously numbered about 9100 and had increased from 1978-1988 at more than 12% per year (Dietz et al. 1989, Heide-Jorgensen and Harkonen 1988). An epizootic in the Soviet Union's Lake Baikal in 1987 killed several thousand Baikal seals (Grachev et al. 1989). Disease outbreaks in other species in the western Atlantic, Pacific, and Antarctic were less severe (Geraci et al. 1982, Hinshaw et al. 1984, Laws and Taylor 1957, Smith et al. 1974, Vedros et al. 1971) but there is no evidence of long-term demographic consequences in those areas; there are no published data on population responses following the 1987 and 1988 disease outbreaks.

### B. Other pinnipeds

Throughout the world, populations of many pinniped species have been increasing at relatively high rates. Northern elephant seals (Mirounga angustirostris), for example, have been increasing at about 14% per year for nearly one hundred years. The duration of increases for other species varies according to the time at which commercial harvesting ended; pre-exploitation abundance of any of those species is unknown. Following sustained population growth in the early 1900s, northern fur seals (Callorhinus ursinus) in the Bering Sea declined substantially, for unknown reasons, from the 1960s through the late 1980s. Northern sea lions have decreased steadily during the past two decades throughout the Aleutian Islands and western Gulf of Alaska, whereas their populations in the eastern Gulf of Alaska, Canada and Oregon and Washington have remained relatively stable or increased slightly. Southern elephant seals have also been declining in most areas of the Southern Ocean in recent years, following a period of recovery from commercial harvesting.

Reproduction of several species of pinnipeds in the Pacific declined in 1982 or 1983 coincident with the 1982/83 El Nino Southern Oscillation (Trillmich and Ono, eds., 1991). That poor reproduction and high pup mortality was evidently related to reduction, redistribution or disappearance of prey populations near rookeries. There is little evidence of substantial adult mortality nor in long-term demographic effects from that intense oceanographic disturbance, exepts perhaps at the Galapagos Islands.

## 3.1.2 Cetaceans

### A. Killer Whales

Geraci (1990) reviewed the effects of oil on cetaceans and included a table of reports of cetaceans associated with oil (Table 2 here). Only one incident involving killer whales was found, in which two whales (one sick, one dead) were observed in association with diesel fuel (quantity unknown) off the Alaskan peninsula.

Aside from occasional reports of mass die-offs or strandings (e.g., Oritsland and Christensen 1982, Christensen 1990), the most significant cause of killer whale morality has been commercial whaling. For example, Christensen (1982) reported that 2399 killer whales were killed in Norwegian coastal waters between 1938 and 1980. This represented a mean annual catch of 57 whales; Christensen (1982) noted, however, that the length (and therefore presumably the age structure) of the catch did not change during that period. Although no population growth rates are available, the percentage of pregnant females ranged from 12-32.8%, as determined by catch data (Anon. 1982). Similar percentages of pregnant females have been calculated from Antarctic catch data (12.72-18.97%). Off Marion Island in the southern Indian Ocean, 36.3% of adult females observed had calves (Condy et al. 1978), although some may not have been young-of-the-year.

From 1962-1977, a total of 66 killer whales were removed from a few pods in British Columbia and Washington by a live-capture fishery to supply captive whales for oceanaria; cropped pods have higher population growth rates and birth rates, and lower mortality rates than uncropped pods.

Using photo-identification, Olesiuk et al. (1990) calculated a number of population parameters for killer whales off British Columbia and Washington. They reported an annual rate of increase of 2.92%; the percentage of mature females pregnant varied from 2.7-4.1%. Neonate mortality was 43%. The mean life expectancy was 50.2 years for females and 29.2 years for males, with predicted maximum life spans of 80-90 and 50-60 years, respectively. From computer simulations the authors predicted that the killer whales in this region could sustain a maximum non-selective harvest of 2.84%. They further predicted that a stationary population at carrying capacity would comprise 37% juveniles, 20% mature males, 14% reproductive females, and 29% post-reproductive females. Leatherwood et al. (1990) reported the following age structure among Prince William Sound killer whales: 22.41% adult males, 9.48% adult females (defined as females in close association with a calf), 3.9% calves, and 64.22% immatures and others (this group includes immature animals, adult females not associated with calves, and recently matured males that lack a prominent dorsal fin).

B. Other cetaceans

Population growth rates and related parameters have been measured in other species that have experienced significant human disturbance, usually in the form of harvesting (either as target species, right whales for example; or incidental catch, dolphins in the Eastern Tropical Pacific (ETP) for example).

The relatively low birth and death rates of killer whales are mirrored by another large odontocete, the sperm whale. Females produce a calf only every 3-6 years, and the natural mortality rate is less than 1% per year (Gosho et al. 1984). A decrease in calving interval (from 6 to 5.2 years) has been documented in an exploited population off Durban, South Africa (Best et al. 1984).

Reilly and Barlow (1986) estimated that dolphins could approach a population growth rate of 9%, but that was unlikely to be attained under most conditions. Barlow (1985) reported the following differences among a more intensively fished dolphin population in the ETP: smaller percent pregnant, larger percent lactating, and larger percent immature than less-exploited dolphin populations in the ETP.

The highest rates of annual population increase in baleen whales are reported for southern right whales and range from 7.6% (Payne et al. 1990) to 11.7% (population as a whole) or 13% (cow-calf pairs) (Bannister 1990). Gray whales have increased at annual rates of about 4% or greater since the early 1900s, despite a harvest rate of about 1.2% per year (Reilly et al. 1983) and Bowhead whales, which are also harvested for subsistence purposes, increased at an annual rate of around 3% from 1978 through 1988 (Zeh et al. 1991). Moderate rates of increase for other whales were summarized by Best (1990). Reproductive rates have been reported for humpback whales; the mean calving rate (calves per mature female per year) is about 0.4 (Perry et al. 1990, Clapham and Mayo 1990). The mean calving interval for gray whales is 2.11 years and the birth rate (ratio of calves to adults) is about 0.14 (Reilly 1984).

3.2 Dependency of recovery on habitat protection, changes in management practices, and other restoration approaches

In virtually all cases, recent population recoveries of pinnipeds and cetaceans has been due to the termination of commercial harvesting or indiscriminate or incidental killing. Many species were reduced to very low levels during the harvesting periods and several were believed to have been exterminated. Presumably, foraging and breeding habitats were not degraded by the harvesting. The presence of abundant prey resources and good quality breeding habitat are probably the most important factors that allow sustained population growth, as soon as commercial exploitation ceases.

Quick resumption of population growth of eastern North Pacific pinnipeds (i.e., California sea lions, northern elephant seals, harbor seals) following the 1982/83 ENSO was evidently due to rapid recovery of prey resources; i.e., the degradation of habitat and reduction of carrying capacity was short-lived.

3.3 Indicators of recovery that are the most practical and cost effective to measure

There are few data available on the pre-EVOS status of killer whales and harbor seals in the affected EVOS area. For harbor seals, relative abundance and distribution and relative annual production of young would be indicators that could be directly compared with early post-spill data and with similar data from comprehensive data bases from other regions. However, collection of data on haulout patterns, movements, and diet would be useful for determining whether changes in local abundance of seals might be due to lowered reproduction among resident seals or simply to movements of surviving seals to more favorable breeding or foraging habitats or to changes in haulout patterns related to dietary shifts.

Photo-identification studies (perhaps in combination with VHF or satellite telemetry) of killer whales should be continued to document relative pod sizes and composition, home range (of residents) and large-scale movements (of residents and transients), and reproductive rates. Those studies should be made over a broader area in Prince William Sound and during more seasons than previous studies. Monitoring in alternate years or every three years would probably be most efficient as the studies should be continued for 15 years or more to provide any useful information on population trends.

Bigg (1982) and Balcomb et al. (1982) measured birth rates, mortality rates and net population change in cropped versus uncropped pods with relatively good success.

### 3.4 Approaches and strategies for how indicators of recovery are best monitored and tested to determine when recovery has occurred

First, "recovery" must be defined for killer whales and harbor seals because there are few or no pre-EVOS data to compare with post-EVOS data. The case harbor seals in Prince William Sound is further complicated by a probable declining trend in abundance prior to the EVOS (cf. Pitcher 1990). To estimate the health of local Prince William Sound populations of these species, a combination of approaches would be most productive and should be conducted every two or three years; evidence of recovery will likely require more than 15-20 years of observation. Combinations of satellite and VHF telemetry, aerial and boat surveys, and ground observations, dietary studies (for harbor seals) and photo-identification studies (for killer whales) should be used but should be planned carefully to give statistically valid results and to avoid the possibility of the studies themselves (i.e., disturbance) complicating interpretations of movements, reproduction and trends in abundance.

These studies need to be integrated with research by other groups on benthic, epibenthic, and mid-water column fish and invertebrate communities to determine the effects of their recoveries on local killer whale and harbor seal distribution.

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Table 1. Summarized oil effects on pinnipeds (from Geraci and St. Aubin 1990).

**Table 4-1**
**Reports of Pinnipeds Associated with Oil**

| Date | Location and source | Oil type and quantity[a] | Species | Impact | Reference |
|---|---|---|---|---|---|
| late 1940s | Antarctic; ship discharge | Fuel oil. Quan. ? | Unspecified seals | Bloodshot eyes; surface fouling with tarry oil | Lillie (1954) |
| 1949 | Ramsay Island, Wales; source unknown | Fuel oil. Quan. ? | Gray seal | Pups largely unaffected by thick coating of oil. Two fouled pups drowned. | Davies (1949) |
| Mar. 1967 | English Channel; *Torrey Canyon* | Crude oil, $30 \times 10^6$ gal | Gray seal | Seals observed surfacing through slick. 3 oiled seals found dead or dying. Up to 12 confirmed deaths. | Gill *et al.* (1967); Spooner (1967) |
| Jan. 1969 | Gulf of St. Lawrence; storage tank | Bunker C, 4000 gal | Harp seal | 10–15,000 seals coated. Unspecified number of dead seals recovered. | Warner (1969); Sergeant (1987) |
| Feb. 1969 | Santa Barbara, Calif.; Union Oil well | Crude oil, $> 30 \times 10^6$ gal | Harbor seal, elephant seal, Calif. sea lion | Oiled seals observed on Channel Islands and along mainland coast. Mortalities not conclusively linked to oil. | Le Boeuf (1971); Brownell and Le Boeuf (1971); Simpson (1970) |
| Nov. 1969 | N. Dyfed, Wales; source unknown | Type ?. Quan. ? | Gray seal | 14 oiled, dead pups found. No causal relationship. | Anonymous (1970b) |
| Feb. 1970 | Chedabucto Bay, Sable Island, N.S.; *Arrow* | Bunker C, $4 \times 10^6$ gal | Gray seal, harbor seal | 50–60 harbor seals and 100 gray seals oiled on Sable Island. 500 oiled seals in Chedabucto Bay. 24 found dead, some with oil in mouth or stomach. | Anonymous (1970a, 1971a) |
| Feb.–Mar. 1970 | Kodiak Island, AK.; ship discharge | Slop oil or oily ballast | Hair seals, sea lions | Est. 500 mammals contacted. No mortalities. | Hess and Trobaugh (1971) |
| Apr. 1970 | Alaska Peninsula; source unknown | Diesel fuel. Quan. ? | Hair seals | 400 seals exhibited unusual behavior. No mortalities. | Anonymous (1971b) |
| Nov. 1970 | Farne Islands; source unknown | Type ?. Quan. ? | Gray seal | Yearling seal found with oil-stained pelt and crusting around mouth. Otherwise healthy. | Bonner and Hickling (1971) |
| Mar. 1972 | British Columbia; *Vanlene* | Bunker B, 100,000 gal | Seals | Seal herds in area unaffected. | Environmental Sciences Ltd. (ESL) (1981) |
| Sept. 1973 | Repulse Bay, NWT; ship discharge | Refuse oil. Quan. ? | Ringed seal | Hunters killed 5 oil-covered seals. | Muller-Willie (1974) |
| 1973 | Dutch coast; source unknown | Type ?. Quan. ? | Harbor seal | Patches of oil inconclusively associated with skin lesions. | van Haaften (1973) |
| 1974–1979 | Cape Town, S.A.; ships and industry | Chronic discharge | Cape fur seal | Fur seals lingering in polluted harbor without obvious effect. | Shaughnessy and Chapman (1984) |
| Aug. 1974 | Straits of Magellan; *Metula* | Crude oil, $14 \times 10^6$ gal[a] Bunker C, $1 \times 10^6$ gal | S. sea lion, S. Am. fur seal | Sea lions and fur seals in the area apparently unaffected. | Baker *et al.* (1976) |
| Aug. 1974 | Coast of France; source unknown | Fuel oil. Quan. ? | Harbor seal, gray seal | Oil in intestine of 1 harbor seal. 3 oiled gray seals, 1 ingested oil. | Duguy and Babin (1975) |
| Sept. 1974 | Pembrokeshire, Wales; source unknown | Type ?. Quan. ? | Gray seal | 2 heavily oiled pups drowned when washed off beach. 25 pups and 23 adults fouled. | Davis and Anderson (1976) |
| Jan. 1975 | Ireland; *African Zodiac* | Bunker C, $1.1 \times 10^6$ gal | Seals | Seals in the area were apparently unaffected. | ESL (1981) |
| Aug. 1977 | Greenland; *USNS Potomac* | Bunker C, $1 \times 10^6$ gal | Ringed seal, other seals | 16 oiled seals observed 1 month after spill. | Grose *et al.* (1979) |
| Mar. 1978 | France; *Amoco Cadiz* | Crude oil, $60 \times 10^6$ gal | Gray seal | 2 of 4 dead seals coated with oil. No causal relationship. | Prieur and Hussenot (1978) |
| May 1978 | Great Yarmouth; *UK Eleni V* | Heavy fuel, $1 \times 10^6$ gal | Seals | 20 oiled seals observed. | ESL (1981) |
| Oct. 1978 | South Wales; *Christos Bitas* | Crude oil, 840,000 gal | Seals | Mortality of 16 of 23 oiled. | Bourne (1979) |
| Dec. 1978 | Shetland Is.; Scotland, *Esso Bernicia* | Bunker C, 370,000 gal | Seals | Some seals oiled. No deaths reported. | Anderson (1981) |
| Feb. 1979 | Latvia; *Antonio Gramsci* | Crude oil, 36,500 gal | Seal | One seal killed by oil. | ESL (1981) |
| Mar. 1979 | Cabot Str., N.S.; *Kurdistan* | Bunker C, $2.1 \times 10^6$ gal | Gray seal, harbor seal | At least 4 gray and 6 harbor seals found dead coated with oil. No causal relationship. Oiled seals on Sable Is. | D. F. Parsons *et al.* (1980); D. F. Marston (personal communication) |
| Nov. 1979 | Pribilof Is., AK.; *F/V Ryuyo Maru* | Fuel oil, 290,000 gal | Northern fur seal | Some oiled dead pups found. Causal relationship not demonstrated. | Reiter (1981) |
| Feb. 1984 | Sable Is., N.S.; Well blow out | Gas condensate | Gray seal | 4 oiled seals observed on Sable Is. No mortalities. | Anonymous (1984) |
| Jan. 1989 | Anvers Is., Antarctica; *Bahia Paraiso* | Diesel fuel, 233,000 gal | Crabeater and elephant seals, southern fur seals | 2 crabeater seals affected. Elephant seals and fur seals oiled but unharmed. | Anonymous (1989); T. De Laca (personal communication) |
| Mar. 1989 | Prince William Sound, Alaska; *Exxon Valdez* | Crude oil, $11 \times 10^6$ gal | Harbor seal, fur seals, and Steller's sea lion | Seals observed swimming in oil. 31 harbor seal, 2 fur seal, and 14 sea lion carcasses with some | D. G. Calkins (personal communication) |

Table 2. Summarized oil effects on cetaceans (from Geraci and St. Aubin 1990)

**Table 6–1**
Reports of Cetaceans Associated with Oil

| Date | Location and source | Oil type and quantity | Species | Impact | Reference |
|---|---|---|---|---|---|
| Feb. 1969 | Santa Barbara, Calif.; Union Oil well | Crude oil, >30 × $10^6$ gal | Gray, pilot, and sperm whales; common and white-sided dolphins | 16 stranded whales and dolphins recovered. No causal relationship | Brownell (1971) |
| Apr. 1970 | Alaska Peninsula | Diesel fuel, quantity ? | Killer whale | 1 sick and 1 dead animal observed. No examination. | Anonymous (1970) |
| 1974 | Japan | Bunker C, 11.3 × $10^6$ gal | Porpoise | 1 dead porpoise found. | Nicol (1976) |
| Oct. 1976 | Aransas Pass, Texas; pipeline leak | Crude oil, 15,500 gal | Bottlenose dolphin | Dolphins swam through oil without apparent effect. | Shane and Schmidly (1978) |
| Dec. 1976 | Nantucket Shoals; *Argo Merchant* | Bunker C, 7.9 × $10^6$ gal | Fin whale, pilot whale, others | 43 sightings of animals in and around patches of oil. No obvious reaction. | Grose and Mattson (1977) |
| Mar. 1978 | France; *Amoco Cadiz* | Crude oil, 60 × $10^6$ gal | White-sided and common dolphins; pilot whale | 6 stranded animals with no firm evidence of oil. | Prieur and Hussenot (1978) |
| Sept. 1978 | Matagorda Bay, Texas; boat grounding | Fuel oil, 3000 gal | Bottlenose dolphin | 20 dolphins swimming through oil without effect. | Gruber (1981) |
| June 1979 | Gulf of Mexico; Ixtoc-I | Crude oil, 70 × $10^6$ gal | Bottlenose and spotted dolphins | Animals sighted in areas with oil-coated debris. Apparently unaffected. | Bergey (1979) |
| June 1979 | Cape Cod, Mass.; *Regal Sword* | Bunker C, 80,000 gal<br>Fuel oil, 6300 gal | Humpback, fin, minke, right whales; white-sided dolphins | Animals feeding, surfacing and swimming through heavy concentrations of oil. | Goodale *et al.* (1981) |
| May 1981 | Outer Banks, N. Car.; *Hellenic Carrier* | Type ?, 3000 gal | Porpoise | Unconfirmed report of dead porpoise. | Anonymous (1981) |
| Mar. 1982 | Rodanthe, N. Car.; Source ? | Tar | Pilot whale | Stranded whale with small patch of dry tar on skin. | Anonymous (1982) |
| July 1984 | Gulf of Mexico; *Alvenas* | Crude oil, >1 × $10^6$ gal | Bottlenose dolphin | 1 dolphin swimming in the midst of oil patches. Others at the edge of the slick. | Owen (1984) |
| Mar. 1989 | Prince William Sound, Alaska; *Exxon Valdez* | Crude oil, 11 × $10^6$ gal | 25 gray, 1 fin, 2 minke, and 3 unidentified whales; 7 harbor porpoises | Stranded carcasses. Possible unrelated natural mortality. | H.W. Braham (personal communication) |

[a] All volumes converted to U.S. gallons, and rounded. 1 barrel = 159 L = 42 gal. 1 ton = 278 gal of bunker oil, 300 gal of crude oil, or 332 gal of diesel fuel.