Distribution, Age, and Sex Composition of Sea Otter Carcasses Recovered During the Response to the T/V *Exxon Valdez* Oil Spill

by

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ABSTRACT.—Nearly 900 sea otter (*Enhydra lutris*) carcasses were recovered in or adjacent to coastal areas affected by the T/V *Exxon Valdez* oil spill. The time of carcass recovery and the condition of carcasses indicate that most oil spill-induced mortality occurred early in the response period. In fact, by 19 May about 70% of the carcasses had been found. The majority of the carcasses (56%) were from Prince William Sound, suggesting that mortality was more acute there than in other geographic areas. Examination of the recovered carcasses indicated that more adult female sea otters were killed by the oil in Prince William Sound and along the Kenai Peninsula than other sex and age cohorts, reflecting greater abundance of adult females in those regions. Many of the adult females in those areas were pregnant or lactating. Pups made up a higher proportion of the carcasses collected in the western portion of the spill zone, reflecting the advanced pupping chronology at the time the search effort reached the Alaska Peninsula and the Kodiak Archipelago.

Sea otters (*Enhydra lutris*) are considered one of the most highly sensitive of marine mammals to oil pollution (Kenyon 1969; Kooyman et al. 1977; Costa and Kooyman 1982; VanBlaricom and Jameson 1982; Hansen 1985; Davis et al. 1986; Geraci 1988; Ralls and Siniff 1988). When oiled, the insulative quality of the pelage of sea otters is lost (Kooymen et al. 1977), resulting in hypothermia and eventually death (Costa and Kooyman 1982; Siniff et al. 1982). Toxic effects of exposure to crude oil through inhalation of vapors or ingestion are also likely, although they were undocumented for sea otters before the T/V *Exxon Valdez* oil spill (Geraci 1988). Oil spilled from the T/V *Exxon Valdez* traveled more than 700 km from its point of origin and affected hundreds of kilometers of coastal sea otter habitat (Galt and Payton 1990). The sea otter population at risk from the oil residing in coastal areas affected by the spill exceeded 15,800 animals (DeGange et al. 1990). We provide

a preliminary analysis of the sea otter carcasses that were found in or adjacent to the oil spill zone during the response to the oil spill, which occurred in spring, summer, and early fall 1989.

Methods

Collection of sea otter carcasses in Prince William Sound began within a few days of the oil spill. As oil exited Prince William Sound and spread westward along the Kenai Peninsula, Kodiak Archipelago, and Alaska Peninsula, collection efforts were initiated in those areas as well. Carcasses were collected by a variety of private persons and persons from State and Federal agencies and private industry. At the peak of the collection effort, more than 100 vessels contracted by Exxon Company, U.S.A., were engaged in capture or collection of marine birds and mammals. Facilities to store dead animals recovered in the oil spill zone were established at Valdez, Seward, Homer, and Kodiak. Sea otter carcasses were usually transported by boat or aircraft to the collection facilities within a few days of recovery.

Collection facilities were staffed with biologists from the U.S. Fish and Wildlife Service and the U.S. Minerals Management Service. Turnover of staff at the facilities undoubtedly compromised the data set to some degree, especially at Seward and Kodiak, and to a lesser extent at Valdez later in the response period. Most of the carcasses were examined for date of recovery, location of recovery, degree of decomposition, degree of oiling, sex, and reproductive status (pregnant or lactating). Age of each carcass was qualitatively assessed by a combination of physical characteristics. Each carcass was measured for length and weight. A premolar was taken from most carcasses for precise aging (Schneider 1973; Garshelis 1984). Fetuses were removed from pregnant females and frozen. Female reproductive tracts were removed and preserved in 10% buffered formalin. Because dates on which the animals were found were rarely the time of death, each carcass was examined to determine if death occurred before or after the spill. At least for Prince William Sound, the degree to which skin and skeletal remains were dried or bleached and the extent to which carcasses had decomposed provided a means for crudely estimating time of death. However, with increasing time after the spill, time of death became increasingly difficult to estimate, especially for those carcasses that had been scavenged. Unless there was evidence to the contrary, all intact carcasses were considered to be from animals that died after the spill. Because the acute period of sea otter mortality in Prince William Sound seemed to be short and the collection effort intense, the bias in estimates of time of death are relatively small for the sound, but the bias may be large for carcasses from the Kodiak Archipelago and the Alaska Peninsula.

Results

Few or no sea otters died in Prince William Sound while the oil stayed near the spill site at Bligh Reef or spread offshore. However, on 27 March, strong northeasterly winds pushed the oil into important sea otter habitat in the central and western portions of the sound. The first otter carcass was brought to Valdez on 30 March, 6 days after the spill. Otter carcasses continued to be recovered in the spill zone until the oil spill response was halted on 15 September.

Most of the spill-induced mortality of sea otters occurred early in the spill period (Fig. 1). By 21 April, 44% (382) of the sea otter carcasses had been found. By 20 May, more than 70% of the carcasses were recovered. Based on conservative adjustments of the amount of time carcasses remained "at large" after death, an even higher percentage of sea otters had died by 20 May. Mortality of sea otters was clearly most acute in Prince William Sound, where about 56% of the carcasses were recovered (Fig. 2). Nearly all of the carcasses in Prince William Sound that were recovered during the response were found within 7 weeks after the spill. Most of those were found within the first 4 weeks after the spill. Similar proportions of sea otters were found along the Kenai Peninsula (21.6%) and in the Kodiak Archipelago (18.0%; Fig. 2). Only 4.6% of the carcasses were found on the Alaska Peninsula. Some of the most badly decomposed carcasses found on the Kenai Peninsula may have originated in Prince William Sound, while some of those found on Kodiak Island may have died on the Kenai Peninsula or in the Barren Islands. The geographic pattern of recovery of sea otter carcasses (Fig. 2) is in strong contrast to the pattern of recovery of bird carcasses, where most of the mortality and recovery occurred outside of Prince William Sound (Piatt et al. 1990).

Sex was recorded for most of the carcasses. Contrasting patterns in the proportions of males and females were evident among areas. At both Kodiak Island and on the Alaska Peninsula, males and females were about equally represented in the

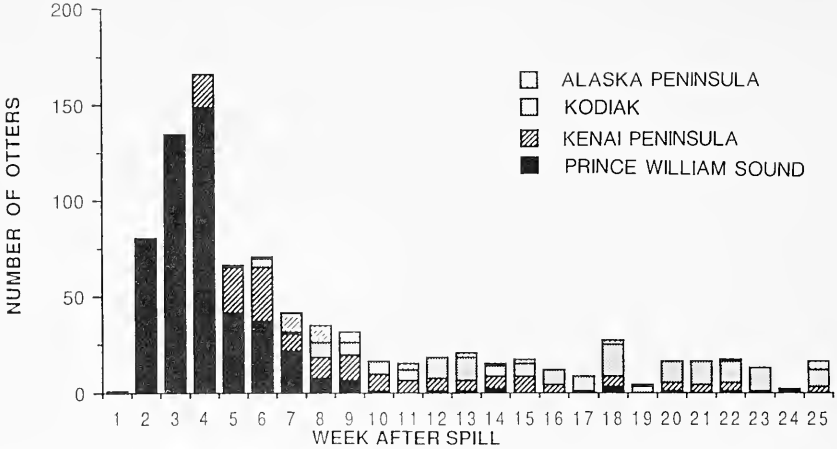

Fig. 1. Number of dead sea otters (*Enhydra lutris*) collected by weekly period after the oil spill.

sample (Fig. 3). The proportion of males and females in the samples from the Kenai Peninsula and Prince William Sound was skewed toward females (Fig. 3). In fact, more than 60% of the sea otters identified by sex from both areas were females. Analysis of the age composition of the carcasses will be completed after analysis of the premolars removed for sectioning is finished. It seems that age composition varied by geographic area. In both Prince William Sound and on the Kenai Peninsula, adults made up a large proportion of the carcasses. Pups were the dominant age class collected at Kodiak and on the Alaska Peninsula. Sex composition also seemed to vary by age. In Prince William Sound and on the Kenai Peninsula, females predominated in the sample of large otters that presumably were adults.

The T/V *Exxon Valdez* oil spill occurred at a time when many adult females were pupping or were in the latter stages of pregnancy. Many of the carcasses of adult female sea otters from Prince William Sound and the Kenai Peninsula that were examined for reproductive status were from animals that were pregnant or lactating.

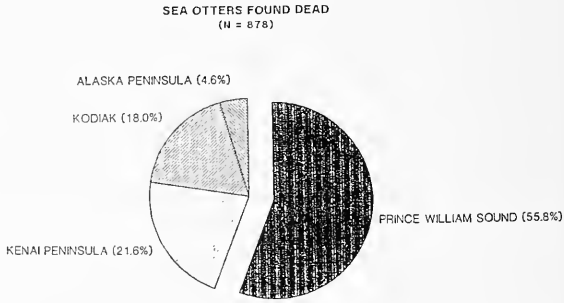

Fig. 2. Proportion of dead sea otters (*Enhydra lutris*) found during the spill response by geographic area.

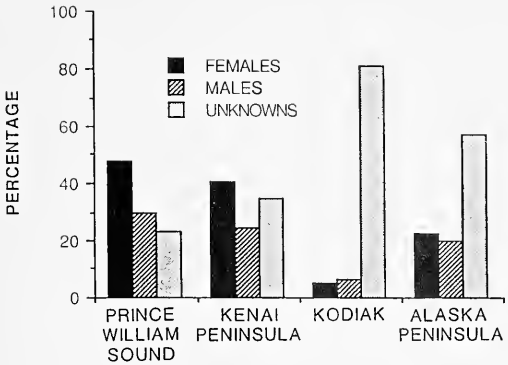

Fig. 3. Sex of sea otters (*Enhydra lutris*) found dead during the oil spill response by geographic area.

Discussion

Two problems confound our ability to estimate the number of sea otters that died as a result of the T/V *Exxon Valdez* oil spill: incomplete information on the proportion of carcasses that represent spill-related mortalities and lack of data on the recovery rates of carcasses. We have assumed that the presence of oil on carcasses is indicative of oil-induced mortality; however, for some otters that died from other causes and later drifted into patches of oil or onto oiled beaches, this assumption is false. For example, many oiled pup carcasses found on the Alaska Peninsula could have been from pups that died from natural causes, and later the carcasses became oiled. As previously mentioned, only 379 carcasses were scored for degree of oiling. Oiling data suggest that a high proportion of animals in the sound were oiled, but outside the sound the proportion of oiled carcasses dropped sharply. More than likely, a large proportion of carcasses in the sound were spill-related deaths, but the proportion of spill-related deaths decreased as the oil spread westward. Data on recovery rates of carcasses are unavailable; however, we can state with certainty that the carcass count, together with the sea otters that died in the otter treatment centers, is an underestimate of the total spill-related mortality.

Data on the timing of recovery of carcasses and the location of recovery suggest that mortality of sea otters was most severe in Prince William Sound. This pattern relates to the extent that sea otter habitat in western Prince William Sound was covered with oil, and the changing characteristics of oil over time (Craddock 1977; Malins 1977). Because of the broad coverage of oil in western Prince William Sound, and the rapidity with which it spread, many sea otters were unable to avoid the oil, even if they tried (Siniff et al. 1982). This is especially true of sea otters in offshore habitats lacking oil-free refugia, such as near Smith and Seal islands, and Applegate Rocks north of Green Island. As oil was carried outside the sound, much of the toxic volatile fractions had evaporated (Galt and Payton 1990), and the oil and seawater formed an emulsion (mousse) that occurred in patches that may have been easier for the otters to avoid. All available data from the carcass collections, capture effort, and condition of live sea otters as they were admitted to the otter treatment centers suggest that fewer sea otters were killed or injured outside of Prince William Sound than inside, and that overall mortality probably decreased with the westward spread of the oil.

What we knew about the age and sex composition of sea otters in Prince William Sound and along the Kenai Peninsula before the oil spill correlated with what we observed after the oil spill. With the exception of pups on the Alaska Peninsula, it seems that sea otters of various sex and age classes were killed in relative proportion to their abundance in each geographic area.

Sea otters were nearly extirpated from their range in Alaska as a result of uncontrolled hunting before 1911, when they received Federal protection (Kenyon 1969; Rotterman and Simon-Jackson 1988). Existing sea otter populations grew out of small remnant populations that persisted in isolated areas (Kenyon 1969). The populations of sea otters that now occupy Prince William Sound and the Kenai Peninsula presumably had as their origin a small remnant population that existed in the southwest corner of Prince William Sound (Lensink 1962; Kenyon 1969).

The pattern of reoccupation of vacant habitat by sea otters in Prince William Sound has been described by numerous authors (Lensink 1962; Pitcher 1975; Garshelis et al. 1984; Garshelis et al.

1986; Johnson 1987; Irons et al. 1988). Typically, male sea otters are the first to invade vacant habitat that may be rich in food resources. At least in some habitats, densities of sea otters are highest during the period of occupation by males (Johnson 1987). As food resources diminish through exploitation by sea otters, the male groups move on to new habitat and the vacated areas are backfilled by breeding females, immature sea otters, and breeding males. The breeding males may move seasonally to male areas on the front of the expanding population (Garshelis et al. 1984). Densities of sea otters and biomass of their prey tend to be lower in female areas than when the same areas are occupied by males. Extensive surveys of the entire sound in 1984–1985 failed to find any distinct male areas (Irons et al. 1988) although portions of Nelson Bay, Orca Inlet, and Hawkins Cutoff are still predominantly male (Monnett and Rotterman 1989). Large segments of the male population, therefore, were safe from the spilled oil.

The portions of Prince William Sound and the Kenai Peninsula that were affected by oil spilled from the T/V *Exxon Valdez* have been occupied by sea otters for many years (Lensink 1962; Pitcher 1975; Schneider 1976; Johnson 1987; Irons et al. 1988). Based on the length of time of occupation, we would predict that females would numerically dominate males in those long-occupied areas. Indeed, the proportion of females in samples of sea otters captured at Green Island in the southwestern part of Prince William Sound during the 1970's and early 1980's ranged from 62–87% (Schneider 1978; Garshelis et al. 1984; Johnson 1987). The sex ratios of sea otter carcasses recovered in Prince William Sound and on the Kenai Peninsula are consistent with the notion that females predominated in those populations.

Not only were many female sea otters killed as a result of the oil spill, but also the spill occurred at a time of intense reproductive activity (Garshelis and Garshelis 1984). Although pups may be present in the population throughout the year (Kenyon 1969; Johnson 1987), a peak in pupping occurs in spring through early summer in Prince William Sound (Johnson 1987; Monnett 1988). The oil spill occurred at a time when many adult females were pupping or near term in their pregnancies. As described above, many of the female carcasses recovered from the Kenai Peninsula and Prince William Sound were from animals that were pregnant or lactating. In addition, portions of western Prince William Sound, particularly the shallow waters near Green Island, are recognized as important pup-rearing habitat (C. W. Monnett, Prince William Sound Science Center, Cordova, Alaska, personal communication). Therefore, not only were many sea otters killed in those areas, but also the most important reproductive component of the population was removed.

The implications for the recovery of the sea otter population residing within the oil spill zone in Prince William Sound and the Kenai Peninsula to prespill levels are uncertain. We cannot predict the extent that repopulation will be limited to growth of the surviving population or result from immigration of sea otters from adjacent oil-free habitats. The long-term effects of the oil spill, resulting from acute or chronic exposure of sea otters to hydrocarbons and other toxic compounds, may affect repopulation through reduced survival, birth rates, or recruitment, thus delaying the recovery of the population. These long-term effects of the spill are under investigation.

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