U.S. Fish & Wildlife Service

Final Revised Recovery Plan for the Southern Sea Otter

(Enhydra lutris nereis)

Final Revised Recovery Plan for the Southern Sea Otter (*Enhydra lutris nereis*)

U.S. Fish and Wildlife Service
Region 1
Portland, Oregon

(Original Approved: February 3, 1982)

Approved: ______________________________
Manager, California/Nevada Operations Office

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Preface

The southern sea otter (*Enhydra lutris nereis*) is listed as threatened under the Endangered Species Act of 1973, as amended, and is therefore also recognized as depleted under the Marine Mammal Protection Act of 1972, as amended. The general goal of the Endangered Species Act is to recover listed species until they are no longer in danger of extinction, or likely to become so in the foreseeable future. Under the Marine Mammal Protection Act, Federal agencies are charged with managing marine mammals to their optimum sustainable population level (i.e., maximizing net productivity of the population). For the sea otter, the optimum sustainable population level is believed to be greater than the population level needed for recovery under the Endangered Species Act. We (the U.S. Fish and Wildlife Service) formed a Southern Sea Otter Recovery Team (Recovery Team) and finalized a recovery plan for the species in 1982. In 1989, we reconvened the Recovery Team and asked them to review and recommend changes to the existing recovery plan.

A draft revised recovery plan for the southern sea otter was completed in 1991. The 1991 draft plan recommended the threshold for delisting under the Endangered Species Act be made equivalent to the lower limit of the optimum sustainable population level under the Marine Mammal Protection Act, which was then believed to be a population size of 5,400 animals with a range extending from Point Conception, California, to the Oregon border. The Recovery Team made this recommendation because they lacked information to quantify particular risks, such as that of major oil spills, to the sea otter population. The recommendation was controversial, however, and the 1991 draft plan was never finalized.

Based on public comments received on the 1991 draft revised recovery plan, the Recovery Team adopted a different approach, population viability analysis (see Soulé 1987), to develop objective delisting criteria for the species as required by the Endangered Species Act. This approach required information on the probability of an oil spill occurring within the range of the southern sea otter, the likelihood of a spill of a particular size occurring, and the expected level of mortality associated with an oil spill event of a particular size. Between 1992 and 1995, we responded to the Recovery Team's need for information by contracting with experts to model oil spill scenarios and evaluate risk to sea otters (see Appendices B and C). In determining a course of action to recover the southern sea otter, we used the best available scientific information as a standard. We assembled a diverse group of stakeholders as technical consultants to review and comment on the recovery criteria and objectives developed by the Recovery Team.

We and the Recovery Team completed the second revised draft of the recovery plan in early 1995. The draft was released for public comment in July 1996. Two significant findings were reported after release of the draft revision. First, the number of dead sea otters stranded on the beach increased significantly from previous years. This increase in dead strandings coincided with a decline in southern sea otter population counts starting about 1995 and continuing through 1999. Second, large numbers of sea otters were reported near Point Conception at the southern end of the range.

As of July 1996, we and the Recovery Team believed that a major oil spill occurring within the sea otter's range remained the primary factor determining the likelihood of otters persisting in California. Therefore, we identified two approaches that would lead to delisting the southern sea otter under the Endangered Species Act: 1) increasing the range of sea otters in California to lessen the risk of a single oil spill event reducing the otter population below a viable level, and 2) decreasing the likelihood of a major oil spill event within the sea otter's range. We based our approach for recovering the species on the premise that, while much progress has been made to reduce the risk to sea otters in California posed by an oil spill, it is not possible to eliminate or reduce the likelihood of a major oil spill sufficiently to consider delisting this population at its 1996 abundance and distribution.

Because of the nature and magnitude of public comments on the 1996 draft revised recovery plan, we requested that the Recovery Team review and make recommendations on the plan a third time. Another draft was released to the public in January 2000. Public comments were reviewed by the Recovery Team in January 2001, and changes based on these comments are incorporated into this final plan. As part of our response to these comments, we asked the Recovery Team to complete a trend analysis to determine the population size that would be robust enough for us to detect a declining trend in abundance reliably prior to the population reaching the threshold for endangered status. In April 2002, we solicited comments from peer reviewers on the methodology used in the trend analysis. These comments are included in Appendix E.

We and the Recovery Team recognize that once the range and number of otters increase sufficiently, or the likelihood of an oil spill event to the otter population decreases to a level yet to be quantified, the southern sea otter will be considered for delisting under the Endangered Species Act. Prior to delisting we must review five listing factors: 1) the present or threatened destruction, modification, or curtailment of habitat; 2) overutilization for commercial, recreational, scientific, or educational purposes; 3) disease or predation; 4) inadequacy of existing regulatory mechanisms; and 5) other natural or man-made factors affecting the population's continued existence. Our findings, if supportive of delisting, will be published in the *Federal Register* as a proposed rule to delist the southern sea otter along with a solicitation of public comments. After reviewing comments received, we will publish our final decision.

In addition, the southern sea otter will continue to be protected under the Marine Mammal Protection Act after its removal from the List of Endangered and Threatened Wildlife (*i.e.*, delisting under the Endangered Species Act); sea otter surveys are expected to continue under administration of the Marine Mammal Protection Act. Furthermore, at present the southern sea otter is automatically treated as a depleted population under the Marine Mammal Protection Act because it is listed under the Endangered Species Act. Based on recent analyses of sea otter carrying capacity (Laidre *et al.* 2001), we currently estimate the lower limit of the optimum sustainable population to be approximately 8,400 individuals. Consequently, after delisting the population will still be below its optimal sustainable population level (thus still qualifying for depleted status), and we will likely initiate or be petitioned to initiate the process of formally designating this population as depleted under the Marine Mammal Protection Act.

In preparing this recovery plan, the Recovery Team has principally cited peer-reviewed literature, as opposed to what is often referred to as "gray literature." Requests for additional information on the details of this plan for recovering the southern sea otter or our justification for specific conclusions should be directed to the U.S. Fish and Wildlife Service. Questions on sea otter biology and management in California should be directed to the U.S. Fish and Wildlife Service, the California Department of Fish and Game, or other organizations that have been active in discussions related to the classification of the southern sea otter as threatened under the Endangered Species Act.

Executive Summary

Current Species Status: The southern sea otter (*Enhydra lutris nereis*) population presently contains about 2,150 animals and ranges between Half Moon Bay and Point Conception along the coast of central and southern California. Range-wide population counts declined at a rate of approximately 5 percent per year between 1995 and 1999, although this declining trend has been less certain in recent years. The translocated colony at San Nicolas Island contains about 27 individuals, including pups. Although more than 70 births are known to have occurred at San Nicolas Island from 1987 to 2002, the population size has remained small and its future prospects are uncertain.

The main threats to the southern sea otter are habitat degradation (including oil spills and other environmental contaminants) and human take (including shooting, entanglement in fishing gear, and harassment). Oil spills, which could occur at any time, could decimate the sea otter population. The reasons for the recent decline in abundance are unknown, but it may be in part related to one or more of the following factors: 1) infectious disease resulting from increased immune deficiencies or elevated parasite and pathogen exposure; 2) incidental mortality caused by commercial fishing activities; or 3) food resource limitation.

Habitat Requirements and Limiting Factors: Sea otters occupy hard- and soft-sediment marine habitats from the littoral zone to depths of less than 100 meters (330 feet), including protected bays and exposed outer coasts. Most individuals occur between shore and the 20-meter (65-foot) depth contour.

The southern sea otter population was exploited to near extinction from an estimated historical population (in California) of approximately 16,000 animals (Laidre *et al.* 2001). Since the early 1970s, population counts have ranged between 1,250 and 2,300 animals. Population counts declined from the mid-1970s to the early 1980s, then increased from the mid-1980s to the mid 1990s. There was little range expansion during the latter period. Between 1995 and 1999, population counts declined, but the population's range expanded both to the south and the north. The current population status is less certain, with recent counts being relatively stable. The decline from the mid 1970s to the early 1980s apparently resulted from entanglement mortality in fishing gear. Once the entanglement problem was identified and rectified through State regulations, the population immediately began to increase again. The cause of the recent decline remains uncertain. In the 20th century, the southern sea otter population never increased at the species' maximum potential of 17 to 20 percent per year, although this rate of increase is typical of recovering populations in Washington, British Columbia, and Alaska (Estes 1990*a*).

The depressed population growth rate for the southern sea otter population is largely due to elevated mortality, as opposed to reproductive depression or emigration. Infectious disease is the single most important known cause of mortality. Other known sources of mortality include shark attacks, shooting, entanglement in fishing gear, and starvation. These sources of mortality are rare or absent in growing sea otter populations in Washington, Canada, and parts of Alaska.

Recovery Objective: Our recovery objective for the southern sea otter is to manage human activities that may jeopardize the continued existence of the species or damage or destroy habitat critical to its survival such that the species recovers to the point where it can be removed from the List of Endangered and Threatened Wildlife. Because the population is currently not increasing, it is not possible to predict if or when the species will be considered recovered under the Endangered Species Act. To remove its designation as a depleted population under the Marine Mammal Protection Act, the population would likely have to increase further (after delisting under the Endangered Species Act) to reach its optimal sustainable population level (equivalent to 50 to 80 percent of its current carrying capacity). The lower bound of the optimal sustainable population level is approximately 8,400 animals for the entire California coast, based on estimated historic population levels.

Recovery Criteria: The Endangered Species Act specifically lists five factors that must be considered in evaluating the status of a listed or candidate species. The following criteria were developed to provide guidance on when reclassification is appropriate. Prior to delisting the southern sea otter or changing its status to endangered, we must undertake a formal review of all five factors, and a summary of that review must be made available to the public for comment. A final determination on classification is based on the initial evaluation of the five original listing factors and public comments.

> ENDANGERED: The southern sea otter population should be considered for reclassification as endangered under the Endangered Species Act if the population declines to a level fewer than or equal to an effective population size of 500 animals (Mace and Lande 1991). Until better information is available, we recommend using a multiplier of 3.7 to convert effective population size to actual population size (Ralls *et al.* 1983), or 1,850 animals. Therefore, the southern sea otter population should be considered endangered if, based on standard survey counts (*i.e.*, spring surveys), the average population level over a 3-year period is fewer than or equal to 1,850 animals.
>
> THREATENED: The southern sea otter population should be considered threatened under the Endangered Species Act if the average population level over a 3-year period is greater than 1,850 animals, but fewer than 3,090 animals.
>
> DELISTED: The southern sea otter population should be considered for delisting under the Endangered Species Act when the average population level over a 3-year period exceeds 3,090 animals.

Actions Needed:

- Monitor southern sea otter demographics and life history parameters to determine population size, rate of change, and distribution. Evaluate supporting habitat for changes in types, abundance, distribution, and use (*e.g.* resting, haul out, feeding, breeding, natal area, peripheral feeding/resting areas, offshore areas) and changes in its estimated carrying capacity by mapping habitat types.

- Protect the population and reduce or eliminate the identified potential limiting factors related to human activities, including: managing petroleum exploration, extraction, and tankering to reduce the likelihood of a spill along the California coast to insignificant levels; minimizing contaminant loading and infectious disease; and managing fishery interactions to reduce sea otter mortality incidental to commercial fishing to insignificant levels.

- Conduct research to understand the factor, or factors, limiting the current growth rate of the California population and refine recovery goals from which management actions can be identified and implemented.

- Evaluate failure criteria for the translocation program to determine if the experimental population at San Nicolas Island has met one or more failure criteria and whether continuation of sea otter containment may jeopardize the sea otter population or hinder recovery.

Estimated Cost of Recovery: The total estimated cost of recovery over 20 years is $10,219,700, plus additional costs that are yet to be determined.

Date of Recovery: Delisting may be considered when the population reaches the delisting criterion of 3,090 individuals. If the population immediately achieved and maintained an annual growth rate of 5 percent (the historic maximum for the California population), it could reach the delisting criterion in approximately 10 years. However, given that the population is currently not increasing, and that the reasons for the lack of increase have so far neither been clearly identified nor remedied, it is not yet possible to predict a likely time to recovery.

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I. Introduction

We (the U.S. Fish and Wildlife Service) approved the first southern sea otter recovery plan in 1982. Since that time there have been numerous additions to our knowledge about the species and several important developments that pertain to conservation and management of the southern, or California, sea otter population.[1] New information obtained through the 1980s is summarized in a detailed species account (Riedman and Estes 1990). A comprehensive summary of information obtained since 1990 on the southern sea otter is not available, although Estes *et al.* (2003) provide a summary of trends in abundance, reproduction, and mortality through 1999. In 1989, we reconvened the Southern Sea Otter Recovery Team (Recovery Team) to review and recommend changes to the existing recovery plan. Based on comments from the Recovery Team, we prepared a draft revised recovery plan and, in August 1991, solicited comments from constituent groups and the general public. A second draft revised recovery plan, released in 1996, incorporated many of the comments that we received on the August 1991 revision. A third draft revised recovery plan, which incorporated new information, was released in January 2000 for public comment. This final revised plan, like the previous drafts, was prepared by us based on recommendations from the Recovery Team.

It is important to note that 1) recovery teams are expected to provide advice on needed recovery actions based solely on biological and ecological considerations; 2) recovery plans that we develop and adopt are not regulatory documents and do not require the cooperating parties to implement recovery actions; and 3) implementation of recovery actions by us or another lead agency may require additional analysis of environmental and social impacts under the National Environmental Policy Act or California Environmental Quality Act.

The southern sea otter has a recovery priority of 9C. This designation indicates that the southern sea otter is regarded as a subspecies with a moderate level of threat but a high potential for recovery. The "C" in the priority designation indicates that recovery of the species may be in conflict with development projects or activities. Specifically, the recovery of the southern sea otter under the Endangered Species Act could potentially conflict with several State-managed fisheries in California, as well as with the transport and extraction of oil and natural gas products along the coast of California.

A. Systematics

A comprehensive study of geographical variation in cranial morphology of the sea otter was done under the U.S./U.S.S.R. Agreement on Cooperation in the Field of Environmental Protection (Project 02.05-61, Marine Mammals). This study provides the strongest evidence to date that the California population should be afforded subspecific status (*Enhydra lutris nereis*) (see Wilson *et al.* 1991). Recent molecular studies indicate that the southern sea otter population has monophyletic mitochondrial DNA and

[1] The terms "southern sea otter," "California sea otter," and "California population of sea otters" have been used interchangeably in the past, and we use these terms interchangeably throughout this document.

several unique mitochondrial DNA haplotypes (*i.e.*, unique genetic components) when compared to the Alaskan populations (Sanchez 1992, Cronin *et al.* 1996).

B. Ecology

1. Distribution and Abundance. The most recent published accounts of the distribution and abundance of the species (*Enhydra lutris*) are provided by Rotterman and Simon-Jackson (1988) and Estes (1992). This information is now more than a decade old and was published before the significant population changes of the 1990s occurred.

Following near-extinction because of exploitation during the 18th and 19th centuries, sea otters were legally protected from take in 1911 through the International Fur Seal Treaty. Because of subsequent population increases, sea otters have recolonized most of the available habitat through the Kuril Islands, Kamchatka Peninsula, and across the North Pacific rim to about Prince William Sound. Populations had recovered to levels at or near carrying capacity throughout much of this region by the late 1980s. However, during the 1990s the number of otters declined precipitously over large areas of western Alaska (Estes *et al.* 1998). The average rate of decline in this region has been about 17 percent per year, for a total population reduction of perhaps 80 to 90 percent in many areas (Doroff *et al*. 2003). The likely cause of these declines is predation by killer whales (Estes *et al.* 1998). Thus, whereas the world population of sea otters was thought until recently to be well in excess of 100,000 individuals, the current total is probably much less. The most recent information indicates that population has declined to a common, low density, at least through the Aleutian archipelago (Doroff *et al*. 2003).

The historical range of the species southeastward from Prince William Sound to central Baja California remains uninhabited except for translocated colonies in southeast Alaska, British Columbia, and Washington, the remnant population in central California, and the translocated colony at San Nicolas Island (Figure 1).

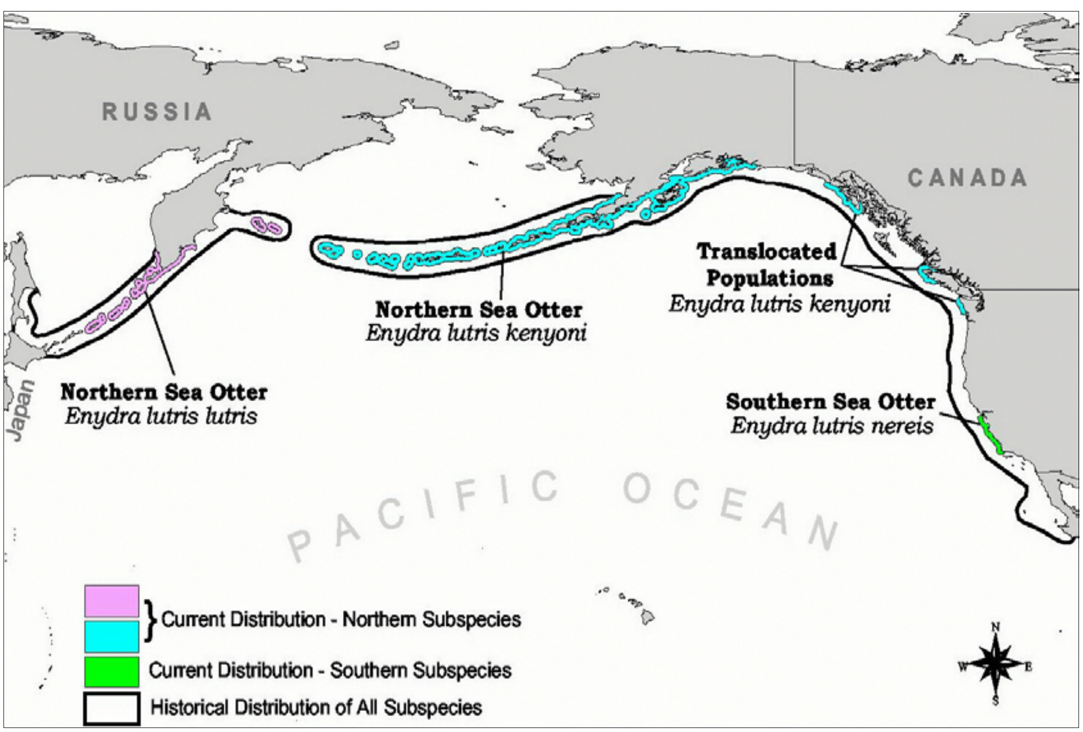

Figure 1. Historical range of the sea otter.

The translocated colonies in southeast Alaska, British Columbia, and Washington increased at rates of 17 to 20 percent per year through the 1980s (Estes 1990a). Unpublished information from periodic or occasional ongoing surveys of these populations indicates that these increases are continuing.

Information on the distribution and abundance of sea otters in California prior to 1990 is summarized by Riedman and Estes (1990). Although both range and numbers have increased during the 20th century, these variables are not well correlated. In particular, whereas population abundance has declined during several periods, distribution evidently has not retracted during these periods.

Range delineation is somewhat arbitrary because individuals frequently wander well beyond the distributional limits of most of the rest of the population. Nonetheless, it is clear that the geographic range of the southern sea otter has expanded considerably since 1938, at which time most individuals occurred from about Bixby Creek in the north to Pfeiffer Point in the south. As the southern sea otter population increased during the following decades, range expansion to the south was always more rapid than it was to the north. By the late 1980s, the range of the southern sea otter had increased to include the area between about Point Año Nuevo at the north and Point Sal at the south. Although the number of otters continued to increase through the mid 1990s, range expansion to the south slowed, and to the north it essentially ceased during this period. By 1995, sea otters were commonly seen as far south as Point Arguello, and in 1998 a substantial number of otters dispersed southward beyond Point Conception (Figure 2).

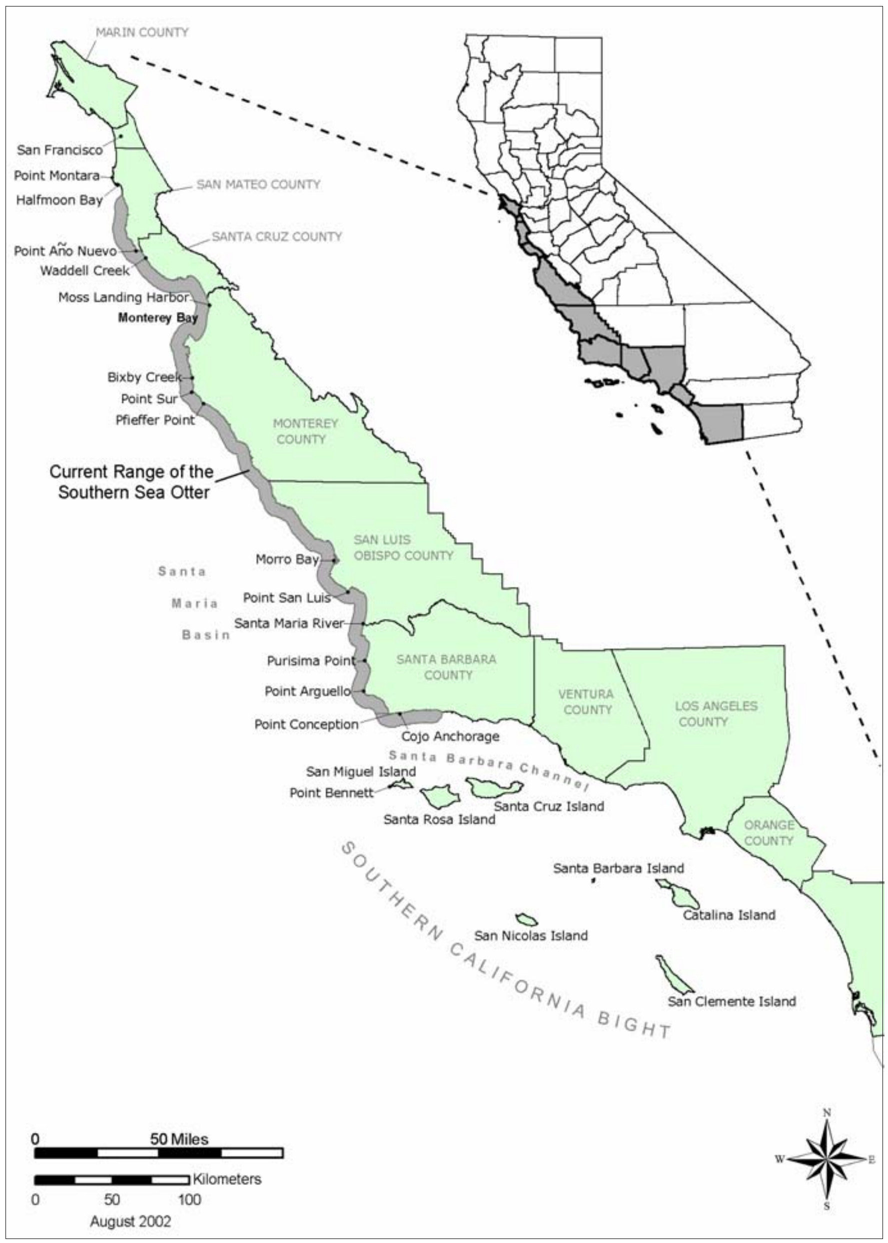

Figure 2. Current range of the southern sea otter.

Population abundance of the southern sea otter has steadily increased throughout the 20th century, except during two periods (Appendix A). By 1976, the population numbered an estimated 1,789 individuals. However, this estimate had declined to 1,443 by 1979, and to 1,372 by 1984.

Standardized range-wide counts were initiated in 1982. Surveys are done during spring and fall, but the spring surveys have traditionally been used to assess population status because they are both consistently higher than fall surveys in a given year and less variable among years. The number of animals counted during the spring surveys remained essentially constant between 1982 and 1985, but thereafter the population steadily increased until 1995, when 2,377 otters were counted (Figure 3). However, in each of 4 successive years (1996, 1997, 1998, and 1999), the total number of animals counted progressively declined, to a low of 2,090 in 1999. This declining trend was evident in both the yearly counts (Figure 3) and in the same data plotted as 3-year running averages (Figure 4). Use of a running average is intended to reduce year-to-year vagaries in any given count, thereby emphasizing overall trends. Recent spring surveys (conducted in 2000, 2001, and 2002) counted 2,317, 2,161, and 2,139 otters, respectively. These most current data suggest that the population is relatively

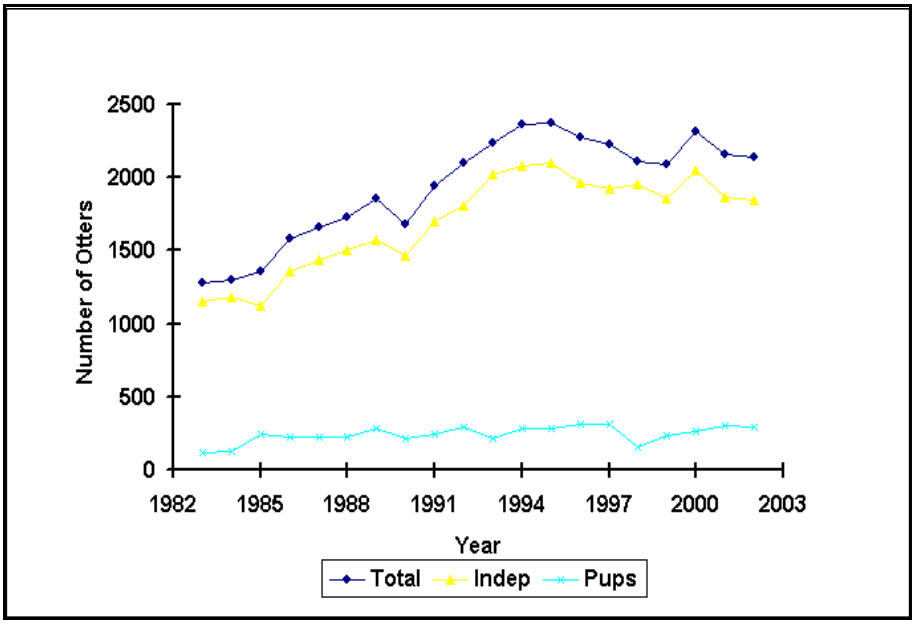

Figure 3. Total number of sea otters counted from 1982 through 2002 during spring surveys. Source: U.S. Geological Survey (2002) http://www.werc.usgs.gov

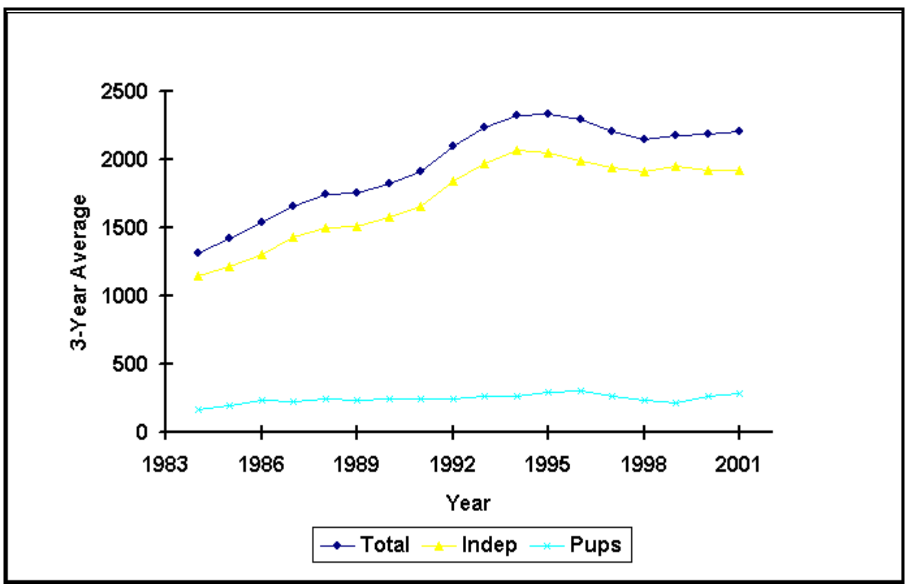

Figure 4. Total number of sea otters counted during the spring surveys, plotted as 3-year running averages. Source: U.S. Geological Survey (2002) http://www.werc.usgs.gov

stable; however, it is unclear whether the declining trend has actually been arrested.

2. Biology. The sea otter is the largest member of the family Mustelidae and the smallest species of marine mammal in North America. As one of the few marine representatives of the order Carnivora, the sea otter evolved to inhabit a narrow ecological zone, adapting to the nearshore ecosystem and preferring rocky shoreline with kelp beds. Body size varies among populations. Adult sea otters average about 30 kilograms (65 pounds) for males and 20 kilograms (45 pounds) for females; average lengths are about 135 centimeters (4.5 feet) and 125 centimeters (4 feet) for males and females, respectively. Forepaws are padded, have claws, and are used in feeding and grooming. Hind limbs are posteriorly oriented and flipper-like for swimming. The tail is less than one-third the body length and of uniform thickness from base to tip.

Figure 5. Sea otter eating crab. Photo by J. G. Hall, from Mammal Images Library, American Society of Mammalogists. Used by permission.

The pelage consists of sparse guard hairs and dense underfur. Underfur density may reach 100,000 or more follicles per square centimeter (650,000 per square inch). Color varies from dark brown to reddish brown, and in older individuals the head, neck, and shoulders often become grizzled. There is little subcutaneous fat and no layer of blubber for energy storage and thermo-insulation as in pinnipeds (seals) and cetaceans (whales). Insulation from cold sea water is provided entirely by air trapped in the fur. The general biology of the sea otter is reviewed in detail by Riedman and Estes (1990).

3. Food Habits. Sea otters eat numerous species of invertebrates (Figure 5) and, in some areas (*e.g.*, Alaska), fishes. By comparing neighboring long-established and recently-established populations from several locations in the North Pacific Ocean, Estes *et al.* (1981) concluded that dietary diversity increased with increased population density and the presumed increase in competition for food. This finding was thought to be consistent with optimal foraging theory because sea otters are known to reduce the abundance of their most profitable prey. However, more recent studies have shown that while there is high variation between the diets of individual sea otters in California, the diet of any particular individual typically consists of only several main prey types (Lyons 1989, Riedman and

Estes 1990, Estes *et al.* in press). Due to reductions in invertebrates and the consequent enhancement of kelp beds and some kelp-associated fishes that follow the recovery and growth of sea otter populations, individual otters from several long-established populations in Alaska and Russia consume large quantities of fish. These interactions enhance production (Duggins *et al.* 1989) and may actually increase the equilibrium density (the density of sea otters when a state of equilibrium amongst habitat components exists) of sea otter populations (Estes 1990a). As sea otter populations declined in western Alaska during the 1990s, kelp forest fishes became rare or absent in the diets of local populations (Watt *et al.* 2000, Estes and Tinker, unpubl. report).

Activity budgets (activity patterns and the amount of time allocated to various activities) have been proposed as indicators of population status (Estes *et al.* 1982, 1986) based on comparative diurnal observations of high- and low-density populations. This indicator is based on the assumption that as growing populations reduce the abundance of their preferred prey, the time required for individuals to achieve their nutritional needs should increase. However, sea otters also feed at night (Loughlin 1979, Garshelis 1983), and there is extensive variation in the activity of individuals both among and within age and sex classes (Ralls and Siniff 1990). Thus, the utility of activity-time budgets to assess population status is debatable (Garshelis *et al.* 1990, Estes 1990*b*, Gelatt *et al.* 2002). Nonetheless, the collective evidence indicates that sea otters spend more time feeding as their populations approach equilibrium.

4. Reproduction. Long-term records from marked individuals have established that most adult female sea otters give birth to a single pup each year (Siniff and Ralls 1991, Jameson and Johnson 1993). The collective data, which are not necessarily representative for the entire population, indicate that the average birth rate of adult females is about 0.90 per year, or perhaps somewhat higher (Riedman *et al.* 1994, Monson *et al.* 2000). In contrast with most carnivores and all other lutrine (otter) species, but consistent with other marine mammals, except the polar bear, litter size is typically one (Estes 1989). Twin births occur rarely, and seldom, if ever, do both young survive to weaning (Jameson and Bodkin 1986). Records from tagged animals also have suggested that females typically attain sexual maturity after 3 years, but that weaning success by primiparous females (females with their first litters) is relatively low (Riedman *et al.* 1994, Monson *et al.* 2000). The age of sexual maturity in males is less well known but appears to be about 5 years. However, the age at which males actually first successfully breed may be somewhat less than or considerably longer than 5 years, depending on population status and social context.

In California, most births occur from late February to early April. The seasonality is not highly synchronous, in that births may occur throughout the year, and the birth peak may extend over several months (Siniff and Ralls 1991). The birth peak is seasonally asynchronous in some parts of central California (Riedman *et al.* 1994).

Age-specific reproductive schedules of sea otters appear to be largely invariant among subspecific populations. Population growth or decline is thus a consequence of variation in age-specific mortality schedules (Estes *et al.* 1996, Monson *et al.* 2000).

5. Mortality. Assessment of sea otter mortality in recent years is based almost exclusively on information obtained from beach-cast carcasses (Estes *et al.* 2003). Two measures are available: 1) the number of carcasses retrieved, and 2) the cause of death in fresh carcasses. The number of carcasses recovered through time shows an overall pattern that is roughly consistent with population growth (Figure 6). However, the relative mortality (measured by dividing the number of carcasses retrieved in a given year by the number of otters counted in the spring survey of that same year) suggests several departures from a time-constant relationship (Figure 7).

These data suggest that mortality was roughly constant at about 5 percent during the period when the population was growing (*i.e.*, from about 1985 through 1995) but was somewhat higher during periods of apparent decline (*i.e.*, the early 1980s and from 1996 through 1999).

Postmortem examinations are conducted by the U.S. Geological Survey's National Wildlife Health Center and the California Department of Fish and Game–Marine Wildlife Veterinary Care and Research Center. Records of cause of death are maintained by the Biological Resources Division of the U.S. Geological Survey. Net entanglement is estimated to have caused an average of 80 deaths per year (Wendell *et al.* 1985) from at least the mid-1970s to the early 1980s. Entanglement mortality appears to have caused the population to decline during that period because restrictions on the use of gill and trammel nets were followed by a resumption of population growth (Estes 1990*a*). There is also evidence that the rate of pre-weaning mortality in central California is higher than it is in growing populations in Alaska (Siniff and Ralls 1991, Riedman *et al.* 1994, Monson *et al.* 2000), perhaps explaining, in part, the comparatively low growth rate in the southern sea otter population. However, the age composition of beach-cast sea otters in California demonstrates that prime-age adults also have experienced elevated mortality rates (Estes *et al.* 1996).

Three possible explanations for the recently increased mortality and reduced population abundance of the southern sea otter have been suggested: increases in the rate of infectious disease; incidental losses in coastal fishing gear; and decreases in food abundance. It should be recognized that two or more of these factors may affect the dynamics of the southern sea otter at a given time. Because thorough necropsies have been done on the fresh carcasses since 1992, it is possible to make a preliminary evaluation of the disease hypothesis. Inasmuch as the elevated mortality rate and declining abundance did not begin until about 1995, the incidence of mortality induced by infectious disease also should have increased concurrently if this factor were solely responsible for population-level changes. There is no clear evidence in the available data for changes in the rate of infectious disease since 1992. However, it should be noted that the level of infestation by acanthocephalan parasites (*Polymorphus* spp.) has apparently undergone a significant increase over the years (Thomas and Cole 1996). In some cases such infestation causes infectious disease(acanthocephalan peritonitis), and it

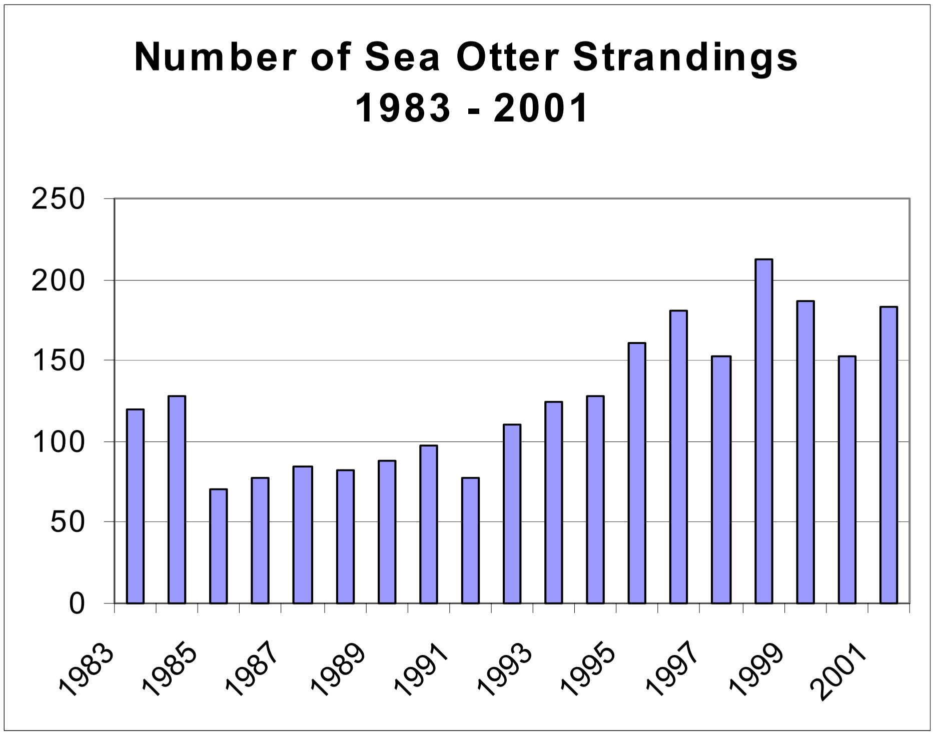

Figure 6. Number of beach-cast sea otter carcasses recovered by year from 1968 through 2001. Source: U.S. Geological Survey, unpublished data (2002)

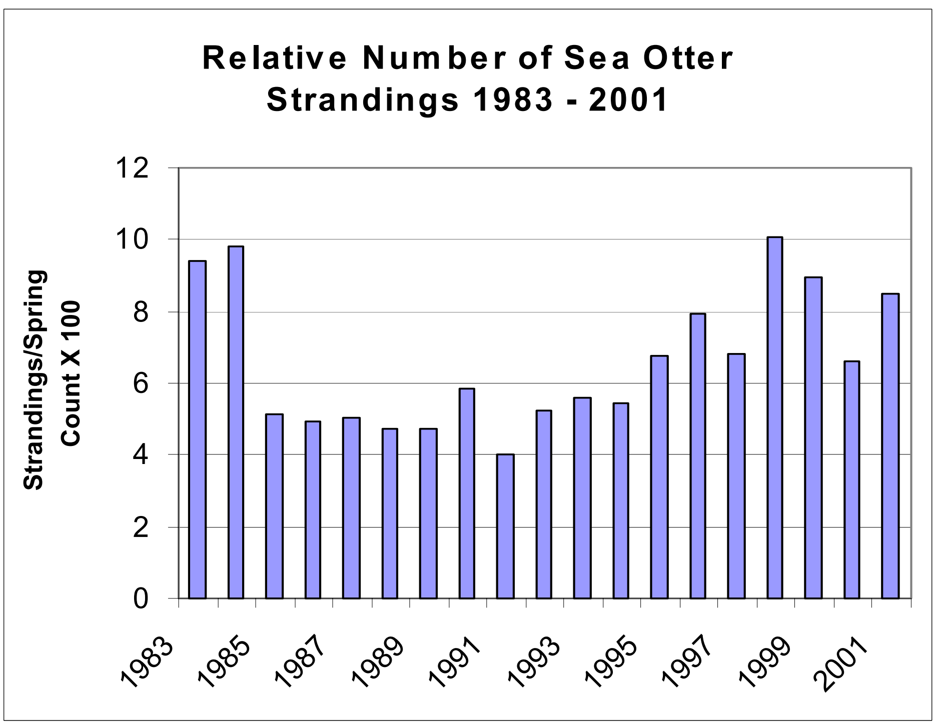

Figure 7. Relative number of sea otter carcasses retrieved by year. Proportions were determined by dividing the number of carcasses recovered by the number of otters counted in the spring surveys (x100). Source: U.S. Geological Survey, unpublished data (2002).

is possible that the increase in infestation has also caused increases in disease rates. Lafferty and Gerber (2002) have shown that the proportion of the population found dead on the beach in any given year is positively correlated with the proportion of carcasses found to have acanthocephalans, which gives a preliminary indication that acanthocephalans may play a role in mortality trends of southern sea otters.

Two further conclusions can be drawn concerning the importance of infectious disease to southern sea otters. The first is that infectious disease must be an important factor in causing the slow growth rate of the southern sea otter population. Because disease is responsible for roughly 40 percent of the deaths in animals obtained from the salvage program, and the reproductive rate of southern sea otters is comparable to that of other populations that are growing more rapidly, it follows that the growth rate of the California population would be substantially higher in the absence of disease. However, the southern sea otter population has never increased at more than about 5 percent per year, which implies that during the period of recovery the magnitude of mortality in California has never been reduced to the levels found in other more rapidly growing sea otter populations. Infectious diseases in the southern sea otter are almost entirely the consequence of parasites and microbes for which the sea otter is not a natural host (K. Lafferty, U.S. Geological Survey, pers. comm.).

While coastal pot and set net fisheries are known to have intensified in recent years, and there are unconfirmed reports of otters having been incidentally drowned, sufficient information to evaluate this potential source of mortality is not presently available. A recent analysis of information from the carcasses recovered during the period 1968-99 indicates that the mortality rate is elevated during the summer months, and that since 1994 the number of carcasses recovered per year is positively correlated with fin fish landings in the coastal live trap fishery (Estes *et al*. 2003).

6. Community Ecology. Evidence gathered to date indicates that there are important interactions between sea otters and the ecosystems in which they live and forage. Otter predation reduces many prey populations, including herbivorous invertebrates exploited in commercial and recreational fisheries. Similarly, the distribution and abundance of food resources likely have important effects on the behavior and population status of sea otters.

The community ecology of sea otters was discussed by various authors in a volume edited by VanBlaricom and Estes (1988). Food web relationships emanating from the influence of sea otter predation in kelp forest communities are proving to be complex and far-ranging (*e.g.*, Irons *et al.* 1986, Duggins *et al.* 1989, Estes *et al.* 1989, summarized by Estes 1996), although much of the work in this area has been done in British Columbia, Alaska, and Russia. Studies in Alaska have shown that sea otters have similarly dramatic and perhaps far-ranging influences in soft-sediment communities (Kvitek *et al.* 1993). Further studies of community relationships are proposed in Recovery Task 4.4.

C. Reasons for Listing

The southern sea otter population was listed as threatened in 1977 because of 1) its small size and limited distribution, and 2) potential jeopardy to the remaining habitat and population by oil spills (42 *FR* 2965, January 14, 1977). A major spill of oil from a tanker in the waters in the vicinity of the range of the southern sea otter has traditionally been considered to be the most serious potential threat to the species. Since listing, however, pollution and incidental take in fisheries have also been recognized as substantial problems. Given that the sea otter population in California is currently not increasing despite the absence of oil spills, and that populations in western Alaska are declining precipitously for other reasons as well, a broader range of threats to the population must be considered. These threats include the possibility of recently introduced disease organisms, mortality incidental to commercial fishing, and the adverse effects of pollution on the general well-being of sea otters. It is also becoming evident that the sea otter and its coastal habitat are threatened by events occurring in adjacent habitats, both on land and in the open sea (Estes *et al.* 1997, 1998**,** Nakata *et al*. 1998).

Petroleum Development Problems. Oil spills have long been thought to be a major threat to sea otter populations. Early studies demonstrated that sea otters are vulnerable to oil contamination (Kooyman and Costa 1979, Siniff *et al.* 1982), and concern over the likelihood of a spill in central California was a main reason for listing the California population. Several recent spills, most notably that of the tanker vessel *Exxon Valdez* in Prince William Sound, have led to a number of conclusions regarding the influence of oil spills on sea otters:

1. The expected number of oil spill events over the next 30 years that are likely to affect the southern sea otter has been estimated. For spills greater than 160,000 liters (1,000 barrels) in the vicinity of the range of the southern sea otter, this estimate is approximately 6 (see Appendix B).

2. The probability of death in sea otters as a result of contact with oil following an oil spill is likely to be no less than 50 percent (see Appendix C). A minimum estimate of 50 percent mortality following contact has been reported; however, this estimate is likely to be lower than actual losses (*i.e.*, negatively biased).

3. Rehabilitation of oiled sea otters following a major spill, where hundreds or thousands of sea otters have been exposed to oil, is expensive, may be detrimental to some individuals, and is of questionable benefit to the population (Estes 1991, 1998). In Prince William Sound, most of the oiled otters were not and could not be captured. Most of the otters that were heavily oiled could not be saved. Some of the otters that were captured and brought to the rehabilitation centers for treatment were either unoiled or so lightly oiled that the stress of capture and rehabilitation efforts may have exceeded the damage, if any, caused by oil.

The above considerations are not intended to diminish the contribution of the State of California in establishing oil-spill response facilities. It can be safely concluded that these facilities will contribute to the rehabilitation of sea otters following spills that are small to moderate in size. However, at this time, we do not believe it is possible to avoid a catastrophic loss to the sea otter population in the event of a major spill in the vicinity of the sea otter's current range.

Oil and Gas Activities on the Federal Outer Continental Shelf Offshore California. Although tanker oil spills have been considered a significant threat to the southern sea otter, offshore oil development and production was not a factor in its listing. However, since 1977, offshore oil and gas activities have increased. Currently, there are 23 oil and gas platforms producing from 43 leases in Federal outer continental shelf waters offshore California. Nineteen of these platforms are located in the Santa Barbara Channel and Santa Maria Basin. In addition, companies have submitted requests for suspensions and schedules of activities for exploration and development of the remaining 36 undeveloped leases, most of which (32) are in the Santa Maria Basin. The 36 leases are organized into 9 undeveloped units and 1 lease. On November 12, 1999, the Minerals Management Service granted the request for suspension.

If all the activities proposed for the undeveloped units are pursued and approved by local, State, and Federal agencies, a number of activities are expected to occur during the next decade or so, including:

1. The maximum use of extended-reach drill technology from existing and new platforms, which will reduce the need for more platforms and exploration rigs.

2. The drilling of six or seven delineation/exploration wells from existing platforms or a single mobile drilling unit and about 10 production wells from existing platforms.

3. The installation of four to six new outer continental shelf platforms.

4. The decommissioning of six to eight existing outer continental shelf platforms.

5. The possible construction of one new onshore facility in northern Santa Barbara County.

6. The retirement of a number of aging onshore processing and handling facilities.

Under this scenario, the physical presence of the oil industry would diminish offshore over the next decade, although current production levels could be sustained for some time to come. All of these actions will undergo rigorous environmental review by the Minerals Management Service under the National Environmental Policy Act and, for those actions that may affect threatened or endangered species, consultation under section 7 of the Endangered Species Act. New or revised oil exploration and development plans for Federal outer continental shelf waters will also require a consistency review by the California Coastal Commission.

D. Past and Ongoing Recovery Efforts

Incidental Take in Fisheries. Sea otters are sometimes killed in fishing gear. Most often the cause of death is drowning when an otter becomes entangled or otherwise trapped in nets or traps. The California Department of Fish and Game manages California's nearshore fisheries and implements regulations to protect sea otters from incidental take.

Gill and Trammel Net Restrictions. Since 1985, the California State Legislature has enacted legislation to reduce the level of incidental take of sea otters in gill and trammel nets. Currently, State law prohibits the use of gill or trammel nets (essentially nets with stretched mesh greater than 8.9 centimeters [3.5 inches]) from Waddell Creek (in Santa Cruz County) to Point Sal (in Santa Barbara County) in waters 55 meters (30 fathoms) or less at mean low water (California Senate Bill No. 2563). The Director of the California Department of Fish and Game may, by public announcement, allow the use of gill or trammel nets in all, or any part of, the area south of Point San Luis (in San Luis Obispo County) to Point Sal for a specific period. This determination must be based on a finding that the use of those nets will not result in any incidental take of sea otters. The Director shall immediately rescind this authorization if (s)he determines that further use of those nets may result in the accidental entanglement or take of sea otters. In April 2002, the Director enacted a temporary emergency closure of gill-net fishing from Point Reyes (in Marin County) to Point Arguello (in Santa Barbara County) in waters 110 meters (60 fathoms) or less. This closure further reduced incidental take of sea otters; it was made permanent in September 2002.

Live Fish Trap Fisheries. In the 1990s, a shallow-water live fish fishery using pot traps developed. Initially, the fishery was largely unregulated, and concern arose that sea otters could become incidentally trapped and drowned. Controlled experiments conducted by the U.S. Geological Survey and the Monterey Bay Aquarium confirmed that sea otters could enter traps with no size restrictions on the entrances. The California Department of Fish and Game now requires 13-centimeter (5-inch) rings to be placed in live fish traps used along the central coast. We provided rings to fishermen during the first year of the program to assist with the transition of the fishery.

Translocation Program. Our 1982 recovery plan identified the translocation of southern sea otters as an effective and reasonable recovery action. The translocation program, authorized by Public Law 99-625, includes two main components: the creation of an experimental southern sea otter colony by means of translocation and the creation and maintenance of a management zone. These elements are discussed below.

Public Law 99-625. On November 7, 1986, the U.S. Congress enacted Public Law 99-625, which specifically authorized the translocation and management of southern sea otters. In accordance with this law, we developed a translocation plan that included the following details: the number, age, and sex of sea otters proposed to be relocated; the manner in which sea otters were to be captured, translocated, released, monitored, and protected; specification of a zone into which the experimental population would be introduced (translocation zone); specification of a zone surrounding the translocation zone that did not include the range of the parent population or adjacent range necessary for the recovery of the species (management zone); measures, including a funding mechanism, to isolate and contain the experimental population; and a description of the relationship of the implementation of the plan to the status of the species under the Endangered Species Act and to determinations under section 7 of the Endangered Species Act. The purposes of the management zone are to facilitate management of southern sea otters and containment of the experimental population within the translocation zone, and to prevent, to the maximum extent feasible, conflicts between the experimental population and other fishery resources within the management zone. Any sea otter found within the management zone is to be treated as a member of the experimental population. Under Public Law 99-625, we are required to use all feasible nonlethal means to capture sea otters in the management zone and to return them to the translocation zone or to the range of the parent population. With the exception of defense-related actions, sea otters in the translocation zone are afforded essentially the same protection as the present population in central California.

Translocation of Sea Otters. The history and status of translocated sea otter populations through the early 1980s is summarized by Jameson *et al.* (1982). Only Alaska sea otters (*E. l. kenyoni*) were used in those translocations. Since that time, the translocated population in Oregon has become extinct, whereas populations in southeast Alaska, British Columbia, and Washington have increased at high rates since becoming established. The estimated sizes of these populations in 1989 were summarized by Estes (1990*a*). An analysis of earlier data indicates that each of these translocated populations declined from 60 to 90 percent of their original size in the year or two following release, followed by a period of slow growth (Estes *et al.* 1989).

In August of 1987, we began translocating southern sea otters to San Nicolas Island in the Southern California Bight. This translocation was undertaken for the joint purposes of management and research, pursuant to the authority of Public Law 99-625. Dispersal of the translocated animals after their release at San Nicolas Island proved to be a serious obstacle to the translocation effort. The translocation strategy changed several times during the project in an effort to circumvent this difficulty. Early results indicated that adults were more prone to leave than juveniles, and subsequently only juveniles were moved. A later analysis, however, indicated that adult and juvenile loss rates were not substantially different, and that the continued translocation of juveniles was also unlikely to result in the establishment of a colony.

The last sea otter was released at San Nicolas Island in July 1990, for a total of 140 sea otters translocated. Of the 140 sea otters released at San Nicolas Island, the fate of 70 is known. Three were found dead at San Nicolas Island within a few days of being translocated. Thirty-six are known to have returned to the parent population range, and 18 were either captured (11) or found dead (7) in the management zone, months to years after they were translocated. At least 13 sea otters are thought to have remained at San Nicolas Island after their release. The remainder are suspected 1) to have returned to the mainland or moved to the management zone, where they have not yet been found, or 2) to have died. Precipitous declines resulting from dispersal similar to that seen at San Nicolas Island were also noted in the translocations to Alaska, British Columbia, and Washington, which were eventually successful, but the numbers of otters in these colonies began to increase within several years. The number of otters at San Nicolas Island has only slowly increased since 1993 and is currently (as of June 2002) about 27 animals, with at least

73 pups having been born into the population.

Maintenance of the Management Zone and Southern Range Expansion of the Mainland Population. Public Law 99-625 requires, as part of the translocation program, the maintenance of a management (otter-free) zone that surrounds the translocation zone. We, in cooperation with the California Department of Fish and Game, are required to implement a containment program for the nonlethal removal of sea otters found within the management zone. Initially, when sea otters were found in the management zone, it was typically as individuals or pairs. These animals either were captured by us and moved out of the management zone, or they left the zone of their own accord. However, in 1990, a group of 10 otters (including 2 pups) was reported near Point Bennett on San Miguel Island. Subsequent observations suggested that this group was resident, a likely consequence of the translocation. Between 1990 and 1993, 14 sea otters (11 independent, 3 dependent) from this area were captured and relocated to the northern portion of the mainland population. In 1993, sea otter containment activities ceased. An aerial survey conducted in October 1999 found four sea otters at San Miguel Island, but a ground survey conducted in September 2001 failed to find any sea otters at the island.

In March of 1998, approximately 65 sea otters were found in and near Cojo Anchorage, just south and east of the northern boundary of the management or "otter-free" zone. By April, the number grew to over 100. Commercial fishermen and recreational sport divers called on us to begin capturing and relocating those animals out of the management zone as directed by the containment provisions of Public Law 99-625.

Scientists familiar with the seasonal movements of sea otters noted that this group of animals was likely to stay in the area through the spring and early summer and return to the parent range during the late summer or fall. There was additional speculation that some animals were likely to return to the Cojo Anchorage area sometime in the late winter or early spring. The sea otters did indeed return, and groups of sea otters have seasonally moved into and out of the management zone each year since 1998. The largest group was observed in February 1999 and numbered 152 animals. The most recent spring sea otter survey, conducted in May 2002, found 8 otters in the management zone.

Members of the Recovery Team and interested environmental organizations expressed concerns to us about the possible adverse effects to the sea otter population if capture and relocation efforts were attempted, recognizing that Public Law 99-625 required that we undertake such efforts. Given recent data indicating that the number of southern sea otters observed during annual counts was declining, these groups raised concerns that the capture and relocation of a large number of sea otters could result in the deaths of animals, disrupt the existing social structure of resident groups, increase competition for resources, and possibly exacerbate population decline.

In 2000, we completed an internal consultation under section 7 of the Endangered Species Act and determined that resumption of the containment program would jeopardize the southern sea otter population (U.S. Fish and Wildlife Service

2000). Removal of sea otters from the management zone has been discontinued pending the results of a reevaluation of the southern sea otter translocation program and completion of a supplement to our original environmental impact statement for the program.

Supplement to the 1987 Environmental Impact Statement. In the late 1990s it became clear that many objectives of the southern sea otter translocation program were not being achieved, and substantial new information had become available concerning the translocation of sea otters. In July 2000, we announced our intent to prepare a supplement to the original Environmental Impact Statement (EIS) for the translocation of southern sea otters released in 1987 (65 FR 46172). Scoping workshops were held, and a scoping report was completed in April 2001. The supplemental EIS will provide updated information and evaluate alternatives being considered for the future of the translocation program. We are planning to release the supplemental EIS for public review in 2003.

Vessel Traffic Management. The National Oceanic and Atmospheric Administration, represented by the Monterey Bay National Marine Sanctuary, and the U.S. Coast Guard began working together in 1997 with key stakeholders to create a plan for managing large vessel traffic (*e.g.*, crude oil tankers, commercial vessels greater than 300 gross tons, and barges) in the Monterey Bay Sanctuary and beyond to reduce the risk of oil spills, groundings, and collisions. A group of stakeholders, including Federal, State, and local governments, environmental groups, and industry, reviewed past practices and risks and recommended a package of strategies. The plan includes the following elements:

Distance from Shore. Recommended distances offshore of Point Sur and Pigeon Point strengthen informal patterns of current practices and, where necessary, shift vessels farther offshore to reduce the level of threats to resources. The recommended distances, by vessel types, are as follows: tankers, 93 kilometers (50 nautical miles[2]); barges, 46 kilometers (25 nautical miles); Hazmat ships, 46 kilometers (25 nautical miles) northbound, 56 kilometers (30 nautical miles) southbound; large commercial vessels 23.5 kilometers (12.7 nautical miles) northbound, 29.6 kilometers (16 nautical miles) southbound off Pigeon Point, 28 kilometers (15 nautical miles) northbound, 37 kilometers (20 nautical miles) southbound off Point Sur.

Large commercial vessels and ships carrying hazardous materials should travel along Recommended Tracks at the above distances, which were approved by the International Maritime Organization in May of 2000 and are now marked on nautical charts. Implementation of this recommendation began in December 2000. Implementation of the recommended distance offshore for tankers would involve negotiation of an industry agreement covering all foreign and domestic carriers of crude oil, building on the existing Western States Petroleum Association agreement covering the Alaskan trade.

Traffic Separation Schemes. Modifications were recommended and implemented for two traffic separation schemes (specific

[2] 1 nautical mile = 1.15 statute miles

traffic lanes that help organize vessels as they approach major ports). The "southern approach" of the San Francisco traffic separation scheme was shifted slightly to the west to reduce the risk of groundings along the San Mateo coastline and to improve north-south alignment with the proposed Recommended Route for large commercial vessels. A 33-kilometer (18-nautical-mile) extension to the Santa Barbara Channel was also recommended and implemented to aid navigation of vessels. These two shifts were pre-approved by the International Maritime Organization in 1990 and 1985, respectively, but required domestic implementation by the U.S. Coast Guard, which occurred in July of 2000.

Monitoring and Reporting. Voluntary radio call-ins by vessels within about 9 kilometers (5 nautical miles) of shore were recommended to report the position of vessels at three points: at Point Arguello, Point Sur, and the existing check in/check out of the San Francisco Vessel Traffic Service. This reporting system would enhance the ability of response agencies to react quickly to an accident or vessel breakdown, enable an evaluation of the effectiveness of routing measures, and provide an opportunity to inform mariners of the sensitivity of the Sanctuary's resources. Timely implementation of an Automated Information System, an electronic system that reports a vessel's position, is also recommended. International implementation of an Automated Information System would reduce the need for some of the intermediate radio call-in points.

Rescue Vessel Network. Development of a Rescue Vessel Network would enable response agencies to identify and direct the nearest potential rescue vessel to the location of a distressed vessel more quickly. This network would allow for the identification of tugs or other vessels capable of rescue and the tracking of their positions by means of the existing system of check-in with the Vessel Traffic Service, the proposed voluntary reporting system, and, when operational, the Automated Information System.

Near-miss Reporting. Timely implementation was recommended for a national near-miss reporting system, which is currently being planned by the U.S. Coast Guard, the Maritime Administration, and industry groups. This system would provide valuable insight into dangerous conditions before they precipitate an accident.

Education. The overall vessel management package should include a strong education campaign for mariners to provide information on the sensitivity of Sanctuary resources, details on the new management measures, and the importance of compliance. A laminated flyer outlining these topics was developed, and 3,000 copies were distributed to the maritime industry in the fall of 2000.

Oiled Wildlife Care Network. The fish and wildlife provisions of California’s Lempert-Keene-Seastrand Oil Spill Prevention and Response Act (OSPRA) (Government Code § 8574.7) parallel or exceed the Federal Oil Spill Pollution Act of 1990 (OPA-90) in most respects. Under OSPRA, the California Department of Fish and Game–Office of Spill Prevention and Response (OSPR) has developed contingency plans to protect wildlife in the event of an oil spill, established methods to assess injuries to natural resources, identified wildlife rescue and rehabilitation stations, and developed restoration plans for wildlife resources (including habitat) following an oil spill. OSPRA also provides for the establishment and funding of the Oiled Wildlife Care Network (OWCN) (Government Code § 8670.37.5) as an essential component of California's wildlife response capability.

The OWCN maintains a corps of professionally trained volunteers, paid staff, and veterinarians. When California wildlife are affected by an oil spill, these personnel retrieve oiled animals, evaluate the animals' need for treatment, and remove oil from the animals. OWCN personnel then rehabilitate affected animals, locate them to suitable release sites, and monitor post-release survival. The OWCN has instituted 24 permanent wildlife care participant facilities along the coast of California. Five facilities with extensive marine mammal care capability and expertise are prepared to cooperate in the cleaning and rehabilitation of sea otters. These facilities include: California Department of Fish and Game–Marine Wildlife Veterinary Care and Research Center (Santa Cruz); the Monterey Bay Aquarium; the Marine Mammal Center (Marin County); Sea World (San Diego); and Long Marine Laboratory (University of California, Santa Cruz). Floating pens for holding large numbers of rehabilitated or preemptively captured sea otters may be installed at Moss Landing Harbor (Monterey County) in cooperation with Duke Energy Power Services or at Horseshoe Bay (Marin County) in cooperation with the National Park Service and the U.S. Army.

More information on OWCN may be found at www.vetmed.ucdavis.edu/owcn/. Copies of California's Wildlife Response Plan, including special procedures for handling sea otters, may be found at www.dfg.ca.gov/Ospr/.

Research. Numerous research projects on sea otters have been initiated or completed since the Southern Sea Otter Recovery Plan was first published in 1982. The major projects concerning southern sea otters are listed below.

Translocation of Southern Sea Otters to San Nicolas Island (U.S. Fish and Wildlife Service). The main research-related purposes of this project were to: i) evaluate and develop techniques for translocating sea otters, ii) evaluate the status of the sea otter population in central California, iii) evaluate the ecological importance of sea otters in nearshore communities, and iv) evaluate and develop methods for containment of sea otter populations. Most studies at San Nicolas Island have been terminated or severely reduced in scope. The colony and the coastal ecosystem are still being monitored.

Determine the status of the southern sea otter population (Minerals Management Service). This study, now complete, had two main purposes: i) to determine the behavior and demography of sea otters in California, and ii) to model the impacts of a possible oil spill on that population. A final report from the study has been published (Siniff and Ralls 1988), as have subsequent papers in peer-reviewed journals (*e.g.*, Ralls and Siniff 1990; Siniff and Ralls 1991; Ralls *et al.* 1989, 1992, 1995, 1996*a*, 1996*b*).

Population biology and behavior of sea otters at the northern end of their range in California (Monterey Bay Aquarium). The purpose of this study is to obtain long-term records of marked sea otters to obtain basic life history information and longitudinal profiles of the behavior of individuals. This study is ongoing and involves OSPR, University of California at Davis, and the Oiled Wildlife Care network. The reproductive data are summarized in Riedman *et al.* (1994).

Causes of mortality in southern sea otters. The purpose of this study is to determine the cause of death in stranded sea otters. An assessment of records obtained from 1968-99 was recently completed (Estes *et al.* 2003). Detailed necropsies of fresh carcasses have been conducted since 1992 by veterinary pathologists from the National Wildlife Health Center in Madison, Wisconsin, the California Department of Fish and Game, and the University of California at Davis. The main finding from this effort is that about 40 percent of the deaths result from infectious disease (Thomas and Cole 1996). These efforts are continuing.

Potential effects of oil on sea otters. Mink were used as a model for sea otters in oil exposure trials. Groups of mink were exposed briefly to oil slicks of Bunker C fuel and Alaska North Slope crude, and other groups were exposed via their diet. Results verified that mink are a good model, and that petroleum released into the environment may have both short and longer term consequences (*e.g.*, reduced reproductive success in both the first and second generation).

Immune response system. Reagents and methods to assess the function of the immune system of sea otters have been developed and are currently being tested on live captured and fresh dead sea otters by veterinary pathologists from the California Department of Fish and Game.

Contaminants in the southern sea otter. Tissue samples were obtained from sea otter carcasses collected in central California, southeast Alaska, and the Aleutian Islands to determine whether contaminant levels were elevated in the southern sea otter. These analyses show that PCB and especially DDT residues occur at elevated levels in the southern sea otter (Estes *et al.* 1997, Bacon *et al.* 1999).

Genetic differential of sea otter populations. Blood and other tissue samples were obtained from sea otters in California, Washington, British Columbia, several regions of Alaska, the Commander Islands, and mainland Russia to determine geographical patterns in the genetic structure of populations. Mitochondrial DNA analysis shows haplotype differentiation among many of these populations, including the southern sea otter (Sanchez 1992, Cronin *et al.* 1996)

E. Summary of the Problem and Basis for Recovery

The southern sea otter population presently contains about 2,150 individuals and ranges along about 500 kilometers (300 miles) of coastline from Half Moon Bay to Point Conception. The population is currently not increasing. In all discussions of population size, the estimate of population is considered to be the number of otters actually recorded during standardized spring surveys. A minimum estimate of historical abundance in California is approximately 16,000 animals (Laidre *et al.* 2001).

The southern sea otter population was listed as threatened in 1977 because of its small size and limited distribution and concern about the effects of human disturbance (especially oil spills) on the population and its habitat. It subsequently became apparent that the population was not recovering quickly, despite Federal and State protection. The original recovery plan (1982) identified the need to establish by translocation one or more colonies to eliminate the possibility that a major oil spill or series of smaller spills could jeopardize the population. The intent behind translocation was to enhance the sea otter's range and population size. The slow rate of population growth, evident in the mid to late 1980s, was viewed as inadequate to expand the sea otter range rapidly enough so that the impacts to the population would be reduced should a spill occur. These factors led to the development of a plan to establish a second colony of sea otters via translocation from central California to San Nicolas Island.

The translocation program was intended to accomplish two interrelated purposes: 1) to establish a second colony sufficiently far from the existing population to minimize the likelihood of simultaneous loss from catastrophic or chronic events, and 2) to serve as a large-scale research experiment. Research associated with the translocation was designed to achieve the following goals: 1) to understand sea otter population dynamics, in particular growth-limiting factors; 2) to understand the ecology of sea otter foraging and the community role of sea otter predation in central and southern California waters; 3) to develop methods for translocating sea otters; and 4) to evaluate and develop methods for containing sea otters. This research was undertaken in response to a significant management dilemma: the protection and conservation of sea otters on the one hand, and the understanding and managing of conflicts between sea otters and shellfish fisheries on the other. These factors were the principal forces behind the joint management/research translocation program put in place in 1987 via the Endangered Species Act, the National Environmental Policy Act process, Public Law 99-625, and Federal regulation.

Four major events have occurred subsequently that alter the need and rationale for the translocation program. These events are listed below:

1. Evidence became available in the early 1980s that entanglement in fishing gear (gill and trammel nets) was having an important limiting influence on the southern sea otter population. Restrictions and closures were imposed, and a subsequent resurgence in population growth was taken as evidence that gear entanglement had indeed caused the population to decline. The establishment of one or more sea otter colonies by translocation was proposed in the original plan because, at that time, the population was not growing, and reasons for the lack of growth were unknown. Active intervention in the form of a translocation was considered necessary to expedite sea otter range expansion to ensure recovery.

With renewed population growth from the late 1980s to the mid-1990s, however, additional translocations were no longer believed to be an efficient means of recovering the southern sea otter population, in large measure because of their high cost and low probability of success. This assessment represented a fundamental change in recovery strategy. The fact that the population is not increasing reinforces the need for this changed recovery strategy. The precipitous declines in sea otter numbers that have recently occurred in western Alaska raise additional concerns about the long-term welfare of the southern sea otter.

2. The *Exxon Valdez* oil spill confirmed many of the worst fears about the consequences of such events. The spill was uncontrollable and spread over 670 linear kilometers (400 miles) in 30 days–an area greatly exceeding the present range of the sea otter in central California plus that of the translocated colony at San Nicolas Island. The distance over which oil rapidly spread during the *Exxon Valdez* disaster indicates that the translocated colony at San Nicolas Island could not provide a reasonable safeguard against an oil spill of this magnitude. Moreover, it is estimated that several thousand sea otters died in the *Exxon Valdez* oil spill (Garrott *et al.* 1993, DeGange *et al.* 1994), a number at least equaling and probably exceeding the present size of the California population. Efforts to save and rehabilitate oiled sea otters were of little or no value to the population.

3. The translocation of southern sea otters to San Nicolas Island has been less successful than originally hoped for as a means of establishing a second, self-sustaining population of southern sea otters (Figure 8). Our final rule for the establishment of an experimental population of southern sea otters (52 FR 29754) described expected population growth at San Nicolas Island in terms of three basic stages: a transplant stage, an initial growth and reestablishment stage, and a post-establishment and growth stage. The

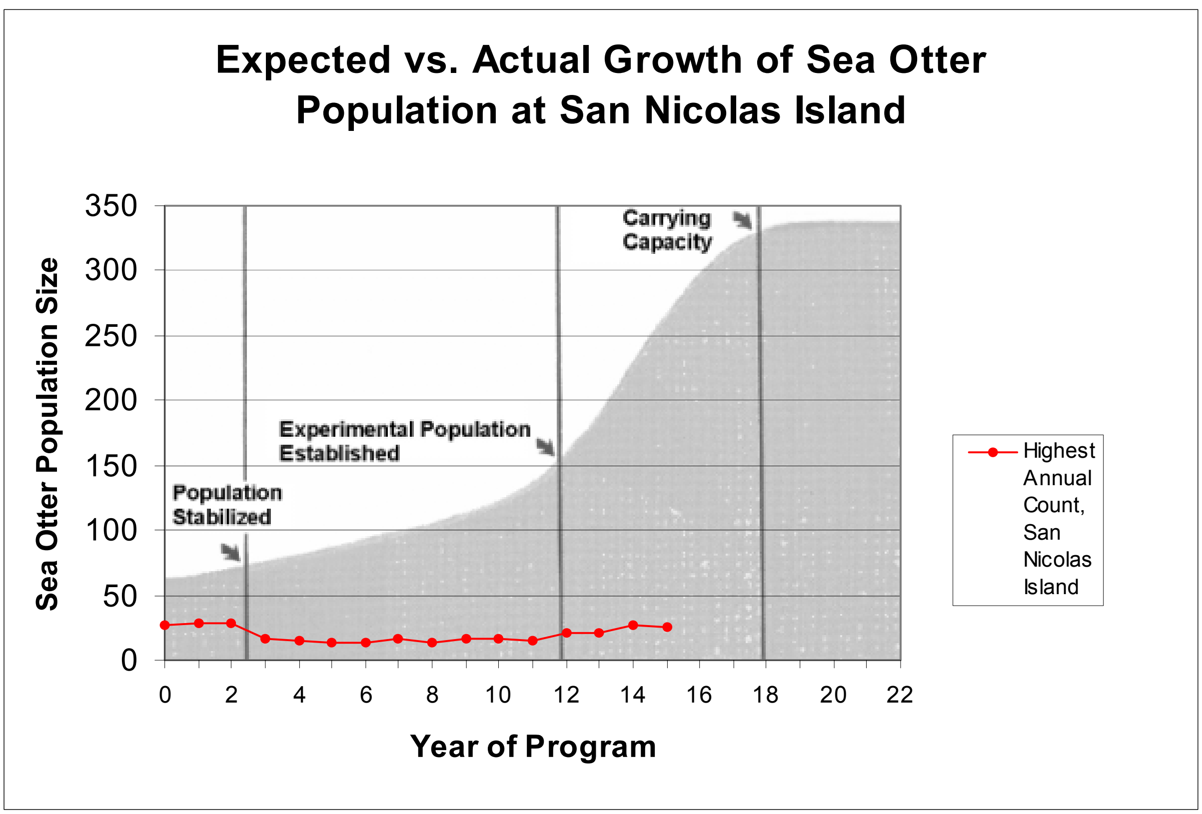

Figure 8. Expected vs. actual growth of sea otter population at San Nicolas Island. Expected growth curve is from original Environmental Impact Statement for translocation program (U.S. Fish and Wildlife Service 1987). Vertical lines demarcate the originally anticipated stages of transplantation, initial population growth and reestablishment, growth of established population, and attainment of equilibrium density at carrying capacity.

transplant stage would end when the population was stabilized, with a sufficient mix of healthy males and females totaling 70 animals (or the number of animals translocated, whichever was less). This stage was expected to require one or more years. The initial growth and reestablishment stage would end when the experimental population was established, with at least 150 animals and a minimum annual recruitment of 20 animals for at least 3 of the most recent 5 years. This stage was expected to require at least 5 to 6 years after stabilization of the population. The post-establishment and growth stage would end when the population reached carrying capacity, an estimated minimum of 280 (but as many as 400-500) animals. A minimum of 10 years was expected for the population to reach carrying capacity.

Figure 8 represents our original expectations for population growth at San Nicolas Island and superimposes our actual results to date. Although 140 sea otters were moved to San Nicolas Island from 1987 to 1990, as of the end of 2002, the population numbered only 29 animals. Some of the translocated animals are known to have returned to the mainland, but the fate of most remains unknown. A similar response occurred following all other translocations, most of which were eventually successful. However, even if the population at San Nicolas Island persists, many years will be required before the population is large enough to be considered an effective reserve to buffer against possible local extinction. In addition, our earlier assumption that the mainland population, if decimated by an oil spill or other event, could be restored using small numbers of animals from the San Nicolas Island colony may not be realistic given the tendencies of translocated sea otters to disperse.

4. Maintenance of a management or "no-otter" zone using nonlethal means has proven costly and ineffective. Large numbers of otters (50-100 animals) have been observed frequenting the northern end of the management zone from 1998 to 2001. These animals appear to move into and out of the zone seasonally from areas along the mainland to the north. Because this movement of southern sea otters initially occurred at a time when the population counts were declining, it is clear that it did not occur as a result of the population increasing in size. Our experience to date indicates that sea otters removed from the management zone are capable of returning to it even after being moved more than 300 kilometers (200 miles). The rapidity with which southern sea otters can move throughout their range makes maintenance of a management zone difficult if not impossible.

Clearly, the intent and purpose of the translocation program have not been met. Therefore, our present strategy for recovering the southern sea otter is to 1) determine the cause of increased mortality, 2) mitigate that cause, and 3) allow the number and range of sea otters to increase to such a size that *a*) there will be enough survivors to recolonize the range without genetic bottleneck effects (loss of genetic diversity due to small population size) in the event of a major oil spill in central California, and *b*) the population will be large enough that we can expect to be able to detect with adequate statistical assurance a declining trend in abundance prior to the population reaching the threshold for endangered status.

Concurrently, effective implementation of the vessel management plan is crucial to minimize the likelihood of future oil spills. The Recovery Team believes that the primary action for promoting the recovery of the southern sea otter at this time should be the cessation of the management zone, and that without such a change in management, the likelihood of recovery will be significantly lessened due to the stress and social disruption of capturing animals and relocating them from the management zone. We have taken this recommendation and other information under consideration and are evaluating alternative courses of action through the National Environmental Policy Act process. After completion of this process, we will issue a record of decision on the future of the translocation program.

Given the problem as summarized above, the remainder of this section describes the recovery criteria, and the basis for these criteria, for southern sea otters. As noted previously, prior to changing the classification of the southern sea otter under the Endangered Species Act, we must evaluate the five factors associated with causing extinction: 1) the present or threatened destruction, modification, or curtailment of habitat; 2) overutilization for commercial, recreational, scientific, or educational purposes; 3) disease or predation; 4) inadequacy of existing regulatory mechanisms; and 5) other natural or man-made factors affecting the population's continued existence. The criteria described below are intended to be triggers that would cause us to move forward with the five-factor evaluation prior to developing a proposal to reclassify the southern sea otter, either to endangered status or to delisted status under the Endangered Species Act.

The minimum population size that can be considered viable is one that is large enough to accommodate natural selection and to allow the population to be resilient to changes in the environment. Franklin (1980) argued that an effective population size (Ne) of 500 is satisfactory on genetic grounds, because at or above this population level the loss of genetic variation due to small population size is balanced or exceeded by the gains of mutation. However, it is important to note that the number of individuals in a population required to achieve a genetically effective population size of 500 may be several times greater than 500 (Frankel and Soulé 1981). Mace and Lande (1991) reported that the genetically effective population size is typically 20 to 50 percent of the actual population size. On the other hand, Lande reported that a minimum of 5000 animals were needed to maintain genetic diversity at an evolutionary time scale (thousands of years). At this point, based on the recommendations of the Recovery Team, we are using a threshold of a minimum effective population size of 500 sea otters as the basis for our management of southern sea otters under the Endangered Species Act. Until better information is available, we will use the 27 percent figure proposed for sea otters by Ralls *et al.* (1983) as the ratio of effective population size to actual population size. Therefore, an actual minimum viable population of approximately 1,850 animals is required to maintain a genetically viable population.[3] This number will be used as

[3] A N_e/N ratio of 0.27, where N_e is the effective population and N is the actual population size, was proposed by Ralls *et al.* (1983). Therefore, minimum viable population size is calculated as 500 times the reciprocal of 0.27 (1/0.27=3.7) or approximately 1,850 animals.

the threshold population level for designation of the southern sea otter population as endangered. That is, the threshold population level of 1,850 animals is the criterion that would trigger a five-factor evaluation of the need to reclassify the southern sea otter as endangered. This criterion may be summarized as follows:

> ENDANGERED: The southern sea otter population should be considered for reclassification as endangered under the Endangered Species Act if the population declines to a level fewer than or equal to an effective population size of 500 animals (Mace and Lande 1991). Until better information is available, we recommend using a multiplier of 3.7 to convert effective population size to actual population size (Ralls *et al.* 1983), or 1,850 animals. Therefore, the southern sea otter population should be considered endangered if, based on standard survey counts (*i.e.*, spring surveys), the average population level over a 3-year period is fewer than or equal to 1,850 animals.

The criteria for listing the southern sea otter as threatened are based on the definition given in the Endangered Species Act: a threatened species is one that is threatened with becoming endangered in the near future. In the case of the southern sea otter, the potential for mortality caused by oil spills continues to be a primary threat. Additionally, the inherent variability in survey counts is such that the population needs to be large enough that we will be able to detect trends in abundance reliably prior to the population declining to endangered status. Therefore, we derive the threshold population level between threatened status and delisted status under the Endangered Species Act as the number of southern sea otters needed to ensure with reasonable certainty that an excess of 1,850 would survive following a major oil spill event, such as the *Exxon Valdez* oil spill (40 million liters [250,000 barrels]), and to ensure that a declining trend of 5 percent per year is detected before the population reaches the threshold level for endangered status. A summary of the assumptions behind our derivation of this number, given the current distribution of sea otters in California and their current population dynamics, follows:

1. There is a threat that a major oil spill will occur in the vicinity of the range of the southern sea otter that could significantly affect the population (see Appendix B).

We and the Recovery Team recognize the importance and capability of the new California Department of Fish and Game oil spill response facilities in California. It is likely that in the event of an oil spill, adverse impacts to sea otters will be mitigated to some unknown extent. However, as the *Exxon Valdez* oil spill demonstrated, it is not possible to eliminate the possibility that, due to weather conditions or other unforseen circumstances, a large number of sea otters will die following a major oil spill, even with the best efforts of the California Department of Fish and Game's oil spill response team.

The Minerals Management Service has assembled data on oil volume released from spills in United States waters involving 160,000 liters (1,000 barrels[4]) or more of

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[4] 1 barrel = 42 gallons or 158.9 liters

crude oil. Based on these and other data (Card *et al.* 1975), 6 spills of 160,000 liters (1,000 barrels) or greater are predicted over the next 30 years in the vicinity of the range of the southern sea otter. The frequency of spills of between 160,000 to 1,600,000 liters (1,000 to 10,000 barrels) is greater than the frequency of spills between 1.6 million and 16 million liters (10,000 and 100,000 barrels). However, even though the probability of a major spill is relatively small, such spills cannot be ignored in the management of the southern sea otter. Large oil spills, even if much smaller than the *Exxon Valdez* oil spill, can potentially affect a large number of otters. For example, in the worst-case expectation for an oil spill of approximately 5 million liters (31,250 barrels), oil would contact 1,119 sea otters (Appendix B). At this time, we do not believe that calculating a specific probability for spills of a specific size or greater is a meaningful exercise relative to defining criteria for the recovery of sea otters in California. Rather, we and the Recovery Team are satisfied that an oil spill of sufficient size to reduce the number of sea otters in California to fewer than 1,850 animals is possible, given current abilities to contain oil (see Townsend and Glazer 1994) and to rehabilitate oiled sea otters.

2. Between 880 and 1600 southern sea otters could contact oil following a 40 million-liter (250,000-barrel) oil spill event (the size of the *Exxon Valdez* spill) in central California (see Appendix B).

The impact of an oil spill on sea otters in California would depend on the size of the spill, the type of oil, the distance offshore of the spill, the location of the spill along the coastline, environmental conditions at the time of the spill, and the nature and effectiveness of containment and clean-up operations and efforts to capture and rehabilitate oiled otters. It is not possible to make exact predictions about how many otters will be contacted by a spill without this information. Based on the simulations summarized in Figure 13 of Appendix B, a 40 million-liter (250,000-barrel) spill in the existing sea otter range would contact approximately 880 sea otters at least 10 percent of the time (90th percentile of distribution). Perhaps more meaningful are the median expected number (50th percentile) and worst-case number of contacts following such a spill, or 100 and 1,600 otters, respectively. We and the Recovery Team believe that using 1,240, a figure intermediate between 880 and 1,600, is both conservative and risk averse (*i.e.*, as uncertainty regarding the number of sea otters to be contacted following an oil spill increases, the estimated number of sea otters contacted will increase). The Recovery Team has recommended against using the worst-case estimate from the simulation studies described in Appendix B because this estimate is highly dependent on the particular scenario modeled in a particular simulation and is therefore expected to change dramatically if a new simulation analysis is performed.

3. In the absence of reliable data on survivability of oiled sea otters in the wild, it is assumed that all sea otters coming into contact with oil will die (see Appendix C).

The available data on sea otter mortality following an oil spill event are inadequate to predict precisely the level of otter mortality that will occur (Appendix C). Specifically, information from the *Exxon Valdez* oil spill event on the mortality rate of oiled otters immediately following the spill is not available, and information on the survival of otters that had already lived through the first week following the spill is likely to be positively biased. Further complications are presented by the difficulty of estimating oil-spill-related mortality rates in California (where the coastline contains relatively few refuges for otters from an oil spill) based on mortality rates in Prince William Sound. Until additional information is available, a conservative approach should be taken. Therefore, we have assumed that all otters contacted by oil within 21 days of a spill will die. From several of the public comments on the 1996 draft of the recovery plan revision, it was clear that this point was misinterpreted by many. The confusion over not using the "worst-case" contact value of 1,600 otters, but rather the 90^{th} percentile value of 880, is understandable. However, to reiterate, given the assumption that 1,240 otters will be contacted by oil following a major spill, we and the Recovery Team recommended further assuming that all sea otters that contact oil will die. Given the efforts of the California Department of Fish and Game to develop oil spill response facilities in California and to implement a protocol for responding to an oil spill in the sea otter's range, this assumption is probably conservative.

4. Over the next 5 years, the distribution of sea otters in California will not change appreciably. This assumption is based on the fact that population size has not increased and the range of the southern sea otter has changed little over the past 5 years.

Because the sea otter population in California is currently not increasing, it is difficult to predict when recovery will be achieved. We and the Recovery Team have assumed that, over the next 5 years, the current distribution of sea otters in California will not change to the extent that the results of the findings reported in Appendix B are invalidated. Should this assumption prove false, we will undertake a re-analysis of the oil spill/sea otter contact simulation studies.

5. A running 3-year average of population size adequately incorporates the existing degree of uncertainty in assessing the abundance of sea otters in California.

The annual rate of increase for the southern sea otter population between 1982 and 1993 was approximately 5 percent per year with a coefficient of variation of 0.09. During this 12-year time period, the number of otters counted from one year to the next increased 10 times and decreased 2 times. Statistically, this fluctuation is not unexpected given the observed coefficient of variation. Whereas using a 2-year running average results in two cases where the population apparently declined one year relative to the previous year, using a 3-year running average results in a more consistent portrayal of population trends. Based on these observations and the recommendation of the Recovery Team, we will use a 3-year running average to characterize population size during a given year. Several of the public comments addressed this recommendation. Specifically, recommendations were made to incorporate a specified rate of increase for some specified period of time into the classification criteria. One such comment from the public was that a criterion for delisting should be that the population has a discrete rate of growth that is greater than 1.0. We and the Recovery Team note that any delisting criteria that require a population to be greater than the current population size meet this requirement. However, the Recovery Team was unable to recommend a specific threshold for a rate of increase that should be associated with delisting at this time.

6. The population size at which the protective provisions of the Act are no longer needed must be sufficiently robust that we will be able to detect trends in abundance reliably prior to the population deteriorating to endangered status.

The actual number of southern sea otters will never be known with certainty, nor will the rate of change be known with certainty. Therefore, the Recovery Team used a simple regression analysis (Gerrodette 1987) to compute the number of years required to detect a trend given the estimated sample variability and rate of change. Two assumptions were made in applying this model: the coefficient of variation (cv), a measure of precision, is 0.1 (10 percent); and increases and decreases in abundance of the California sea otter population are approximately linear. Assuming a sample variation in annual counts of 10 percent and a population decline of 5 percent per year, it would take 10 years to detect reliably (*i.e.*, type I error equals 0.10) a decline prior to reaching a population size of 1,850. A 5 percent rate of decline over a 10-year period resulting in a population of 1,850 animals would require an initial population size of 3,090. In other words, a population of 3,090 animals or larger (*i.e.* 1,850 + 1,240) is sufficiently large that we can expect to be able to detect with adequate statistical assurance a significant (*i.e.*, greater than 5 percent per year) declining trend in abundance prior to the population reaching the threshold for endangered. Based on comments from the Recovery Team, we believe it is reasonable to assume that annual counts of sea otter abundance can be made with a coefficient of variation of 10 percent or less, although this parameter is not estimated as part of the current survey protocol.

In summary, given that the goal of management prior to delisting the species under the Endangered Species Act is to have a minimum of 1,850 otters in California following a major oil spill event and also to be able to detect reliably a population decline before reaching this number, the necessary abundance of sea otters in California, averaged over a 3-year period, is equal to 1,850 (the minimum viable population size), plus 1,240 (a size sufficient to incorporate an expected level of mortality from an oil spill the size of the *Exxon Valdez* and to allow for the reliable detection of a population decline), or 3,090 animals.

Accordingly, the preliminary or milestone criteria for threatened and delisted status for the southern sea otter under the Endangered Species Act are as follows:

> THREATENED: The southern sea otter population should be considered threatened under the Endangered Species Act if the average population level over a 3-year period is greater than 1,850 animals, but fewer than 3,090 animals.
>
> DELISTED: The southern sea otter population should be considered for delisting under the Endangered Species Act when the average population level over a 3-year period exceeds 3,090 animals.

The above regression analysis uses relatively simple statistical methods and incorporates the best information currently available on southern sea otter populations. However, it should be noted that the analysis assesses recovery criteria with respect to trends in single-year counts rather than considering multiple-year averages, and may potentially be sensitive to assumptions about sampling error and survey bias. Following recommendations of the Recovery Team, we plan to conduct a more complex simulation-based analysis to evaluate the robustness of the recovery criteria in this context. If available, the results of this simulation analysis will be incorporated into the next status review or recovery plan revision for the species.

Furthermore, we and the Recovery Team recognize that, should the population of southern sea otters achieve the preliminary delisting criteria, a full evaluation of all five factors for listing specified in the Endangered Species Act would have to be undertaken prior to a change in status. The evaluation should include a calculation of the probability of the population remaining above or below the relevant threshold population level. For example, if the population were being considered for delisting, it would be reasonable for us to calculate the probability that the population would remain above the threshold for delisting (3,090 animals) over the next 10 years. Similarly, if the population were being considered for uplisting to endangered, it would be reasonable for us to calculate the probability that the population would remain below the threshold for endangered (1,850 animals) over the next 5 years. Many of the parameter values used to determine the preliminary listing and delisting criteria are also tentative (*i.e.*, ongoing analyses may produce better estimates of one or more of the parameter values). For example, additional studies on the trajectories of oil spills in California based on oceanographic and meteorological data might significantly improve the estimate of the number of otters that could be contacted by spilled oil. Likewise, improvements in the ability of the oil industry and the State to contain oil and to rehabilitate sea otters following a major oil spill could change the expectation of the number of otters likely to be contacted following a spill and the number of oiled otters that would be expected to survive.

However, it should be recognized that the number of otters that make up this population will never be known with certainty. Nor will the rate of change be known with certainty. Therefore, it is necessary for the classification criteria to incorporate uncertainty and the extent to which changes in abundance can be reliably detected. Based on public comments and recommendations from the Recovery Team, we believe that an adequate minimum threshold difference between the criteria for endangered and threatened status is 1,240 animals. This number is roughly the decrease in animals over a 10-year period that could be detected reliably with the current level of precision in counting sea otter abundance off the coast of California if the decline were at a rate of 5 percent annually. This number also represents a plausible number of otters that might be killed in a short period of time if there were an oil spill of a magnitude comparable to that of the *Exxon Valdez*.

F. Strategy of Recovery

The southern sea otter population, as of spring 1995, occupied approximately 384 kilometers (240 miles) of coastline in central California and consisted of approximately 2,400 animals. The most recent survey data (spring 2002) indicate that the population numbers about 2,150 animals and occupies approximately 500 kilometers (300 miles) of coastline in California. Oil spills remain a primary threat to the persistence of this population, although the fact that the population is currently not increasing in the absence of any such spill-related effects points out that other factors are of importance as well. Oil spills have traditionally been afforded disproportionately great concern because they were thought to be uniquely capable of causing catastrophic, short-term declines. However, the large-scale catastrophic declines in sea otters that have recently occurred in western Alaska are clearly not the result of oil spills. Therefore, oil spills may not be the only threat with the potential for causing short-term decimation or extinction of the southern sea otter population.

The magnitude of potential large spills and their effects were well illustrated by the 1989 *Exxon Valdez* oil spill in Prince William Sound, Alaska. Minimizing the likelihood of oil spills through implementation of an effective vessel management plan is thus critical to sea otter conservation, though it is unlikely that the threat of a major oil spill can be completely eliminated. Because of the inherent difficulties in establishing colonies of sea otters by translocation and the likelihood of an oil spill affecting southern California, the translocated population of otters at San Nicolas Island cannot be considered significant as a reservoir for repopulating the parent population in the event of a spill. Therefore, the sea otter population in California must be allowed to expand in number and distribution to levels that will secure its natural persistence in the event of a major oil spill or series of smaller spills.

Based on the recommendations of the Recovery Team, we have concluded that additional translocations are not the best way to accomplish the objective of increasing the range and number of sea otters in California. We believe that range expansion of sea otters in California will occur more rapidly if the existing population is allowed to recover passively than it would under a recovery program that includes translocating sea otters. Further, the Recovery Team believes that, given changed circumstances such as the recent observed decline in abundance and the shift in the distribution of otters to include the range designated as an otter-free-zone, it is in the best interest of recovery of the southern sea otter population to declare the experimental translocation of sea otters to San Nicolas Island a failure and to discontinue the maintenance of the otter-free-zone in southern California. The details supporting this recommendation are provided in Appendix D. We are currently reevaluating the translocation program through the National Environmental Policy Act process. If the translocation program is declared a failure, the Recovery Team believes it would be beneficial to allow the otters currently on San Nicolas Island to remain there rather than capturing them and returning them to the mainland population.

II. Recovery

A. Objectives and Criteria

The overall recovery goal under the Endangered Species Act is to establish the long-term viability of the southern sea otter population sufficiently to allow delisting the species. To achieve this goal, coastal vessel traffic should be regulated (or managed) in a way that will minimize the risk of accidents in and near the southern sea otter range, and the southern sea otter population must be allowed to increase in number and range.

The primary objectives of this recovery plan are to create the conditions that will allow the southern sea otter to increase in numbers and distribution and to identify appropriate conservation actions to address the threats to this species. Such actions include, but are not limited to, determining the cause or causes of the population's lack of growth, identifying actions necessary to mitigate those causes, continuing efforts to reduce the probability and impacts of an oil spill in and near the sea otter's range, and continuing efforts to minimize the incidental take of sea otters in coastal net and trap fisheries.

Our recovery strategy is to create the conditions that will enable the southern sea otter population to increase to a size that allows the species to persist following most natural or human-caused perturbations. This level is expected to be met when the population size reaches an average level of 3,090 animals or greater over a 3-year period. This delisting criterion is based on information currently available and may be revised on the basis of new information (including research specified as recovery tasks). Prior to any decision to delist this species, we will complete a status review of the southern sea otter evaluating all five factors identified in the Endangered Species Act. We recognize that both the current population and the minimum population size necessary for delisting under the Endangered Species Act are well below the optimal sustainable population level for this species and that the southern sea otter will likely continue to be considered a depleted population under the Marine Mammal Protection Act.

Given that the population is currently not increasing, it is not possible to predict if or when recovery will occur. The cause or causes of the lack of population growth must be determined and mitigated to the extent possible. Although the cause or causes of the lack of population growth remain unclear, initial efforts will focus on elimination of mortality incidental to commercial fisheries and curtailment of habitat degradation that may be causing or contributing to mortality of the southern sea otter.

A summary of the listing criteria, associated threats, and recovery tasks for the southern sea otter is given in Table 1.

Table 1. Summary of Threats and Recommended Recovery Actions.

LISTING FACTOR	THREAT	RECOVERY CRITERION	TASK NUMBERS
A	Restriction of range due to management zone	1	Evaluate translocation program in light of changed circumstances and determine whether one or more failure criteria have been met (see Task 5)
C	Disease	1	Collect and analyze tissues for evidence of stress or disease; determine sources of disease agents and stress; minimize factors causing stress and disease (see Tasks 1.2, 4.3.4, 4.3.5, 4.3.6)
D	Incidental take in fishing gear	1	Evaluate causes of otter mortality; monitor incidental take in commercial fisheries; evaluate the effectiveness of fishing regulations for preventing sea otter take; evaluate incidental take in trap/pot fisheries; determine and take possible steps to reduce or eliminate sea otter mortality incidental to fisheries (see Tasks 1.2, 3.1.1, 3.1.2, 3.1.3, 3.1.4)
E	Oil spills	1	Implement and monitor USCG vessel management plan; assess current risk of tanker accidents and other sources of oil spills, including off-shore oil platforms, pipelines, and marine terminals; implement an oil spill contingency plan that includes a sea otter response plan (see Tasks 2.1.1, 2.1.2, 2.2)
E	Contaminants	1	Evaluate causes of otter mortality; analyze tissues from southern sea otters for environmental contaminants and archive tissues for future analysis; determine sources of environmental contaminants; determine contaminant levels in sea otter prey and habitat (see Tasks 1.2, 4.3.1, 4.3.2, 4.3.3)
E	Intentional take	1	Evaluate causes of otter mortality; minimize intentional take (see Tasks 1.2, 3.2)

Listing Factors:
A. The present or threatened destruction, modification, or curtailment of its habitat or range
B. Overutilization for commercial, recreational, scientific, or educational purposes (not a factor)
C. Disease or predation
D. The inadequacy of existing regulatory mechanisms
E. Other natural or manmade factors affecting its continued existence

Recovery Criterion:
1. The average population level over a 3-year period exceeds 3,090 animals.

B. Narrative Outline

1. Monitor existing and translocated populations.

We recognize that one of the most critical activities concerning the conservation and management of the southern sea otter will be to continue ongoing monitoring programs for population abundance and distribution. Given the rapidity with which otter populations can decline (see Estes *et al.* 1998), surveys should be performed at a minimum of once a year and ideally twice a year. Population count data are the only effective measure of trends in abundance and are critical in evaluating the success of measures taken to mitigate the currently high level of mortality. Further, because the definition of recovery is dependent on these data, ongoing systematic population monitoring is required to determine when the species has recovered sufficiently to allow delisting.

1.1 Monitor the abundance and distribution of otters in California.

Standardized surveys of the mainland southern sea otter population, initiated in 1982, should be continued twice annually (in May and November) to monitor trends in the size and distribution of the population. Those segments of the population's range that are accessible by road and suitable for counting from shore should continue to be surveyed by teams of two observers using binoculars and Questar telescopes. The areas counted from shore should be divided into units that can be surveyed by a single team in no more than 2 to 3 days. Each unit should be surveyed by progressing among established observation posts from which contiguous viewing areas can be counted. The location, group size, activity, and number and size (small or large) of dependent young should be recorded on field maps. Aerial surveys from fixed-wing aircraft should be used to provide counts of the remaining areas that cannot be surveyed from shore. Similar measurements should be taken in the aerial surveys. Similarly, the population of sea otters at San Nicolas Island (and any other location in the Southern California Bight) should be monitored. The data should be tabulated and entered into a database file after each survey and used to establish updated trends in abundance, range, density, and pup production of the southern sea otter population. These surveys would need to continue through the time of delisting, and should be continuous and comparable with post-delisting monitoring surveys developed under task 1.3 below.

If the proportion of the population counted from the ground surveys changes appreciably over time, it is recognized that a calibration study would be necessary to evaluate the potential for bias in estimating trends in abundance and total abundance.

This database will serve as the principal means of assessing the status of the southern sea otter population and should be reported annually by us to the Congress, Marine Mammal Commission, and California Department of Fish and Game.

1.2 Evaluate the causes of mortality of otters that strand on California beaches.

Salvaged otters can provide an enormous amount of information on the population with no removals or harassment of individual otters. Necropsy data are critical in evaluating various hypotheses concerning how stress and disease interact to limit growth rates in sea otter populations. Mortality data (sex ratios, age composition, percent mature, percent pregnant, condition indices) are valuable in testing hypotheses concerning trends in status that could be expected as populations recover. Finally, information on the cause of death (disease, fishery-related, etc.) is important in determining which factors are responsible for the reduced rate of increase in the southern sea otter population and whether these factors can be mitigated.

We, the California Department of Fish and Game, U.S. Geological Survey, and our other research partners have continued this type of monitoring as an ongoing activity over the last 30 years. In 1992, the National Wildlife Health Center (U.S. Geological Survey, Madison, Wisconsin) began a necropsy program of beach-cast carcasses. This program has begun to provide important new information on the causes and patterns of mortality. In 1998, the California Marine Wildlife Veterinary Care and Research Center began participating in the necropsy program to evaluate causes of sea otter mortality. Because mortality has been identified as the general agent of depressed growth in the southern sea otter population, the National Wildlife Health Center and the California Marine Wildlife Veterinary Care and Research Center should continue this program to obtain adequate sample sizes for analysis of causes of mortality.

We have received reports concerning the illegal killing or injury of otters. However, the occurrence of such incidents appears to be low and sporadic. Therefore, direct monitoring of this threat is not warranted. Rather, we should pursue incidents on a case-by-case basis and indirectly monitor annual losses of otters caused by illegal killing by enhancing the existing marine mammal salvage program of the National Marine Fisheries Service. Where illegal killing is suspected, carcasses will be recovered and X-rayed to determine if an animal has been shot. The number of strandings and necropsy results should be reported annually.

Finally, data on the dates and locations of sea otter carcass recoveries have not been compared with data regarding the locations and magnitude of gill net fisheries in different years and seasons to look for a possible cause-effect relationship. Likewise, data concerning the types and levels of contaminants, parasites, and evidence of diseases found in beach-cast carcasses have not been thoroughly analyzed to determine if any of the data vary by location. Preliminary evaluations suggest that the sources of certain contaminants or diseases may be localized. A more comprehensive evaluation of the relevant data sets should be completed.

1.3. Develop and implement a post-delisting monitoring plan.

Before delisting the southern sea otter, a post-delisting monitoring plan should be developed. This monitoring protocol should yield data that is readily comparable to the current monitoring methods, and should have adequate power to detect significant population declines that might cause us to reconsider the decision to delist. Costs of implementation are dependent on specifications of the monitoring plan, yet to be developed. Post-delisting monitoring under the Endangered Species Act should continue for at least five years; in addition, continued monitoring to assess population status relative to the optimum sustainable population under the Marine Mammal Protection Act is expected to continue indefinitely after delisting.

2. Implement plans to reduce the probability of an oil spill occurring in the sea otter range and a plan to minimize the effects of an oil spill on the otter population, in the event that one occurs.

Oil spill risk from large vessels that traffic along the California coast remains a primary threat to the sea otter population. A plan was completed by the U.S. Coast Guard and Monterey Bay National Marine Sanctuary to reduce oil spill risk from vessel traffic. The focus of additional efforts should be on promoting and developing resources for full implementation of existing plans to reduce oil spill risk.

2.1 Minimize the risk of vessel accidents and other possible sources of oil spills and associated threats.

Oil spill risks within and adjacent to the sea otter's range should be identified and a plan developed to minimize oil spill risk to the southern sea otter population.

2.1.1 Implement vessel management plans that minimize the risk of vessel accidents and other possible sources of oil spills.

During 1997 and 1998, the National Marine Sanctuary and the U.S. Coast Guard worked with a diverse group of representatives including Federal, State, and local governments, the oil and shipping industry, and environmental groups to develop vessel traffic management measures to protect the Monterey Bay Sanctuary (which effectively covers the mainland range of the southern sea otter) from the threat of a catastrophic oil spill. As part of this effort, these groups reviewed the available information on vessel routes and operations (including relevant statutes, regulations, and enforcement programs), the current level of risk of an oil spill, and the means available to minimize risks. The group's recommendations are provided in Part I of this plan.

Our original goal was to establish a vessel routing distance from shore such that an oil spill occurring within those lanes has a 1 percent chance or less of contacting the current sea otter range, and, if an accident occurs, an emergency response vessel can arrive from the port of origin and secure the disabled vessel prior to its grounding. Marine terminal operators should have a contingency plan and response equipment capable of immediately responding to and effectively containing and cleaning up a large-scale spill of any type of petroleum product transferred. With the exception of the 1 percent standard, which could not be met because of logistical constraints and the need to reach consensus, these goals have been achieved. The current vessel routing plan provides for volunteer compliance with International Maritime Organization approved routing lanes. The U.S. Coast Guard should monitor compliance by vessel operators to determine if the vessel management strategy is effective. If vessel operators are not adhering to the standards, the U.S. Coast Guard and the National Oceanic and Atmospheric Administration should pursue more stringent regulations.

2.1.2 Assess the degree to which vessel routing and oil spill response planning have reduced the risk and possible impacts of oil spills in and near the southern sea otter range.

Undertake an evaluation to determine the probability over the next 30 years of a major oil spill occurring in the vicinity of the southern sea otter range (including that from off-shore oil platforms, pipelines and marine terminals), and the degree to which the population may be affected, given recent and proposed changes in shipping routes and the State's and industry's ability to effectively respond to an oil spill.

2.2 Implement an oil spill contingency plan that includes a sea otter response plan.

If a large spill occurs within or adjacent to the sea otter's range, otters would likely become oiled and many or most of these animals would die. Although contingency planning efforts are not expected to protect large numbers of sea otters, rescue efforts to protect sea otters would most likely be implemented. The California Department of Fish and Game–Office of Spill Prevention and

Response has established an Oiled Wildlife Care Network that includes five facilities that are equipped and prepared to assist with the cleaning and rehabilitation of oiled wildlife, including sea otters. The location of oil spill containment, dispersant, and clean-up equipment has been identified in area plans as required by the Oil Spill Prevention Act of 1990. The California State legislature has made it mandatory that the oil industry operating in California maintain, by contract or other approved means, equipment and trained oil spill response teams. Deployment strategies within marine waters are typically under the direction of the U.S. Coast Guard, and the response teams engage in regular practice exercises. The expected effectiveness of various response procedures has been documented. Federal law (Endangered Species Act and Marine Mammal Protection Act) charges us with the protection and conservation of the sea otter, and actions may vary from no action to the capture, cleaning, and rehabilitation of oiled animals. We must work cooperatively with the State of California and other partners to implement an oil spill contingency plan and reduce the impact of oil spills on the southern sea otter population. (These plans are different from those that are required of tank ships, non-tank vessels and marine facilities under the OSPR contingency plan regulations.)

The California Department of Fish and Game–Office of Spill Prevention and Response has developed a Wildlife Response Plan for California, which includes special procedures for handling sea otters. This plan should be periodically updated and revised to address clearly the responsibilities and authorities of the U.S. Fish and Wildlife Service and the California Department of Fish and Game, and should include detailed guidance regarding advance preparation, capture, rehabilitation, and release of sea otters in California following an oil spill event. A response plan identifying specific actions for each agency and support organization should be appended, including pertinent names, positions, and phone numbers. A damage assessment strategy and implementation plan should also be included as an appendix.

3. Continue efforts to assess and to reduce or eliminate the incidental take of sea otters in coastal net and trap fisheries and other sources of take in California.

Sea otters are known to become entangled in gill and trammel nets and to swim into and become entrapped in pots and traps used in fisheries for various decapod crustaceans (crabs and lobsters) and fin fishes. Estimates of the incidental mortality of southern sea otters due to entanglement in gill nets during the late 1970s and 1980s exceeded 5 percent of the estimated population size in some years. Gillnet mortality was estimated to be zero between 1991 and 1994, but entanglements apparently increased again after 1994. Between 1995 and 1998, 0.7 to 1.3 percent of the southern sea otter population was estimated to have been killed per year in gillnets in Monterey Bay (Forney *et al*. 2001). Clearly, this level of mortality is significant. If it does not prevent recovery, it will certainly delay recovery and expose the population to increased risk of extirpation following a major oil spill. It is critical that the southern sea otter population be managed to expand in size and distribution as rapidly as possible to minimize the risk of losing the entire population. For this purpose, incidental and intentional take should be reduced to levels approaching zero mortality. It should be noted that Public Law 99-625 and 1994 amendments to the Marine Mammal Protection Act do not authorize the taking of sea otters incidental to commercial fisheries, except in the management zone.

As of January 1, 1991, with the 55-meter (30-fathom) closure for coastal gill and trammel nets (see Conservation Measures in text, California Senate Bill No. 2563), sea otter mortality from net entanglement was thought to have been virtually eliminated. In addition, in 1990 the National Marine Fisheries Service started an observer program using at-sea observers, providing data on incidental mortality rates relative to the distribution of fishing effort. The National Marine Fisheries Service observer program was active from 1990 to 1994, discontinued between 1995 and 1998, and reinstated in the Monterey Bay area in 1999 and 2000 because of concern over increased harbor porpoise mortality. Based on a detailed analysis of fishing effort, sea otter distributions by depth, and regional entanglement patterns during observed years, the National Marine Fisheries Service recently estimated southern sea otter mortality in the halibut set gillnet fishery to have been 64 in1990, zero in 1991 to 1994, 3 to 13 in 1995, 2 to 29 in 1996, 6 to 47 in 1997, 6 to 36 in 1998, 5 in 1999, and zero in 2000 (Cameron and Forney 2000, Carretta 2001, and Forney *et al*. 2001). The increase in estimated mortality in 1995 to 1998 was attributed to a shift in set gillnet fishing effort into areas where sea otters are found in waters deeper than 55 meters (30 fathoms). In September 2000, the set gillnet fishery was restricted by emergency regulation to protect sea otters and seabirds. The State of California has subsequently (September 2002) implemented a permanent ban on gill net fishing in waters shallower than 110 meters (60 fathoms) between Point Reyes in Marin County and Point Arguello in Santa Barbara County. We expect the implementation of this ban to virtually eliminate sea otter mortality in set gillnets north of Point Arguello. This case illustrates the importance of coordinating efforts to monitor fisheries and bycatch with other Federal and State agencies, and such collaborations should continue in the future.

3.1 Continue efforts to document levels of incidental take in various fisheries and to identify and implement measures necessary to eliminate or minimize this source of mortality.

3.1.1 Monitor the incidental take of sea otters in commercial fisheries.

We have coordinated efforts with the National Marine Fisheries Service to monitor sea otter mortality in coastal fisheries that take other marine mammal species under National Marine Fisheries Service jurisdiction. Other fisheries that take sea otters should also be monitored. Estimates of annual mortality should be made based on observed rates of mortality and total fishing effort, stratified by area. Reports of incidental take are currently relayed to us and the California Department of Fish and Game and, where possible, carcasses are recovered, examined for tags, and examined (or necropsied) for probable cause of death. Life history data are also collected. We should continue to coordinate monitoring efforts with the National Marine Fisheries Service to ensure that otters in newly occupied range (such as near Point Purisima) are not compromised by fishing activity. We should also make efforts to monitor any existing, new or expanded fisheries that a) use gear types known to have the potential to catch sea otters, and b) take place in areas used by sea otters.

3.1.2 Prepare a report that evaluates the effectiveness of regulations on the use of gill and trammel nets in California waters over the last 15 years.

Regulations imposed upon the gill and trammel net fishery to protect sea otters were first promulgated by the State of California in 1984. Continual take of sea otters in areas outside the restricted isobath (line indicating equal depth below the surface of a body of water) resulted in a series of additional regulations to protect the sea otter. Presently, gill and trammel net fishing is restricted to outside the 110-meter (60-fathom) isobath (under regulations finalized in September 2002) throughout most of the sea otter's range. This information should be assembled into a single report evaluating the effort to reduce incidental take by State regulation.

3.1.3 Evaluate the potential for incidental take of sea otters in trap and pot fisheries.

A coastal live trap fishery for kelp forest fishes developed in the early to mid 1990s, and its growth is coincident with a trend reversal (from increasing to declining) in abundance of the southern sea otter population. Laboratory experiments confirm that sea otters willingly enter these traps in apparent quest for the food they contain. Furthermore, unconfirmed reports indicate that sea otters have entered these traps and drowned in the wild. While the influence of any such losses on sea otter population trends remains uncertain, measures are needed to eliminate the possibility of sea otters being killed incidentally in these pot and trap fisheries.

Some work has been done to evaluate the effectiveness of steel rings placed in the entrances of traps. The California Department of Fish and Game now requires 13-centimeter (5-inch) rings to be placed in live fish traps used along the central coast. A survey of pot and trap fishermen concerning any observations of interactions (either loss of catch, damage to gear, or incidental mortality) should be conducted. Additionally, salvaged sea otter carcasses in areas where trap and pot fisheries occur should be examined for evidence of drowning. Further studies should be undertaken with captive sea otters to determine if and how otters get caught in traps and pots and to devise and evaluate additional mitigation measures.

3.1.4 Determine and take possible steps to reduce or eliminate sea otter mortality incidental to fisheries.

The information from the previous sub-tasks should be integrated into a single document summarizing sources of incidental take, current level of take, and effectiveness of previous efforts to reduce take. This document should also recommend actions necessary to reduce the level of take to near zero.

3.2 Minimize intentional take of southern sea otters.

As the southern sea otter population increases in number and range, malicious activities directed at the sea otter may increase. Measures to quickly identify and minimize these activities need to be implemented. Based on information obtained from the sea otter mortality monitoring program and other information obtained from law enforcement investigations, we and the California Department of Fish and Game should evaluate the nature and extent of intentional take of sea otters and develop a program to minimize its occurrence.

4. Evaluate assumptions used to estimate the population level at which southern sea otters could be considered recovered under the Endangered Species Act.

The Endangered Species Act requires recovery plans to include measurable recovery criteria. The criterion for delisting is based on the probability of an oil spill reducing the sea otter population to a level where it is likely to become in danger of extinction within the foreseeable future. It also incorporates the number of animals required to ensure that a declining trend of 5 percent per year can be reliably detected before the population reaches the threshold level for endangered status. Recovery of the southern sea otter depends critically on continued population growth; time to recovery is a direct function of the population growth rate.

Therefore, the present lack of growth of the southern sea otter population is a matter of concern. Additional studies are needed to 1) determine if human-caused factors have reduced the growth rate of the southern sea otter population below the potential for the species and whether or not the potential growth rate can be restored and 2) refine projections of how rapidly sea otters will expand their range and how this population would respond to a major oil spill that affected a significant portion of their range.

4.1 Estimate the current probability of the population being below 1,850 over the next 10 years. Incorporate this analysis into delisting criteria.

The delisting threshold of 3,090 animals was derived based on a population size that was large enough to withstand a decline in abundance over a reasonable time period that would be detectable prior to the population reaching the threshold for endangered (*i.e.* 1,850 animals). This calculation assessed trends in single-year counts based on empirically observed rates of change in the California population, and assumed that measurement error was the dominant source of variation in modeling population trajectories. To evaluate the sensitivity of the recovery criteria to these assumptions, an analysis that incorporates all sources of uncertainty (including bias and annual population fluctuations) should be undertaken to evaluate the robustness of the recovery criteria and the use of the 3-year running average approach to define the endangered and threatened thresholds. This analysis should be completed within the next 5 years and incorporated into the next revision of the Southern Sea Otter Recovery Plan.

4.2 Evaluate differences in life history parameters for sea otter populations throughout the North Pacific.

Sea otter populations in various geographic locations exhibit a wide range of growth rates and are thought to differ in life history parameters such as age-specific survival rates. The available information on sea otter life history parameters and population growth rates should be compiled and synthesized to better define the way in which the California population may differ from sea otter populations in other areas.

The following parameters should be estimated for several populations of sea otters: 1) gender-specific survival rates from birth to weaning, weaning to age 1 or 2, and adult survival; 2) average gender-specific size (*i.e.*, weight) at age 1, 2, and 3 years; 3) diurnal and nocturnal percent of time spent feeding; 4) species composition of the diet within the population and among individuals; 5) age of first reproduction; and 6) adult rate of reproduction.

The life history data should be used with population models to determine such things as 1) the critical life history stages in limiting sea otter population growth; 2) how local patterns of population change are related to identifiable life history features; 3) recovery times from various population depletion scenarios; and 4) demographic changes responsible for the cessation of population increase at carrying capacity.

A final report, based on the findings of these research programs, should compare life history parameters from different populations of sea otters and reach a conclusion regarding the differences between populations. Recommended management and research actions should be included.

4.3 Determine concentrations and possible effects of disease, stress, toxic trace elements, and organochlorines on sea otters.

Members of the mustelid family are among the most sensitive mammalian species to polychlorinated biphenyls (PCBs) and methyl mercury (Wren *et al.* 1987). PCBs and other toxic chemicals have been suspected in population declines of wild mink and a closely related species, the river otter (MacDonald and Mason, 1982). Chronic dietary exposure of hexachlorobenzene has been shown to adversely affect mink and ferret reproduction (Bleavins *et al.* 1984).

Risebrough (1989) reviewed data on concentrations of trace elements and organochlorine hydrocarbons in the southern sea otter collected over a 20-year period in California. PCBs in liver tissues of southern sea otters were in higher concentrations than those associated with reproductive failure in minks (Bacon *et al*. 1999). Risebrough (1989) recommended future study of synthetic organic contaminants in the sea otter's food web. These contaminants occur routinely in central California marine food webs (Martin 1985).

A study of organic pollutants in sea otters was recently completed (Bacon 1994, Bacon *et al*. 1999). Liver samples were collected from beach-cast or native harvested sea otters in three general regions: central California, southeast Alaska, and the central and western Aleutian Islands. It was anticipated that organic contaminants, already known to occur at unusually high concentrations in the California Current ecosystem, would be higher in the livers of animals from California than from Alaska. Sea otters from southeast Alaska had low levels (trace to fewer than 5 micrograms per kilogram of tissue wet weight) of the various classes of contaminants measured, thus providing a good standard of comparison as a "clean" population. Comparatively high levels of contaminants were measured from southern sea otters. Average concentrations of dichlorodiphenyltrichloroethane (DDT) and dichlorodiphenyldichloroethylene (DDE) were 846 micrograms per kilogram of tissue wet weight, and the level of total PCBs was about 200 micrograms per kilogram. Surprisingly, PCB levels in the Aleutian Islands exceeded those measured from southern sea otters, and DDT/DDE levels from the Aleutian otters were significantly greater than those from southeast Alaska.

Because otter populations in the Aleutian Islands were thriving at the time of the study, it is unlikely that PCBs alone are having a significantly detrimental impact on the southern sea otter population. However, impacts from the high DDT/DDE levels are less clear, and a collective or synergistic effect of the generally high level of organic contaminants in southern sea otters cannot be excluded.

Subsequent studies of contaminants founded in stranded southern sea otters have identified accumulation patterns of organochlorine pesticides and PCBs in southern sea otters stranded along the coast (Nakata *et al*. 1998) as well as the presence of butyltin residues, which are known to be immunosuppressant (Kannan *et al*. 1998).

Diseases, including acanthocephalan peritonitis, encephalitis (caused by the protozoan *Toxoplasma gondii*, which completes its life cycle in cats and can occur in cat feces), coccidioidomycosis, and various bacterial infections, are a significant but inadequately understood source of mortality for southern sea otters, and may be limiting population growth. Additional research is needed on population impacts, sources, transmission routes, and appropriate preventive measures related to infectious diseases.

4.3.1 Analyze tissues from southern sea otters for environmental contaminants and archive tissues for future analysis.

The high levels of organic contaminants in sea otters from California and far western Alaska are a matter of substantial concern. Although the use of some of these compounds is currently banned in the United States, they are being used in increasing amounts elsewhere in the world. Further, long-lasting pollutants are one of the most insidious threats to coastal marine ecosystems. This threat is especially relevant in California because of the large expected human population increase in California and the high likelihood that many of these people will live near the coast. Obtaining accurate measurements of contaminant residues in sea otter tissues is therefore critical. Since the literature is replete with examples of erroneous differences in various parameters due to handling and analytical techniques, as part of this task: 1) a standard protocol should be followed by all investigators cooperating on this project, 2) sample size requirements should be developed, and 3) a Quality Assurance/Quality Control (QA/QC) program should be initiated to reduce between-lab variability.

4.3.2 Determine the sources of environmental contaminants.

Although source identification of contaminants is difficult, there are many techniques that can provide useful information in this regard. Compounds from specific sources often have identifiable signatures. An evaluation of potential and likely sources of contaminants (*e.g.*, agricultural runoff, antifouling paints, treated waste water, municipal solid waste composts) to southern sea otters should be compiled and reported.

4.3.3 Determine contaminant levels in sea otter prey and in other components of the coastal food web and ecosystem.

Environmental contaminants that enter sea otters probably do so almost exclusively through their food. Therefore, it is important to know whether the contaminants are being obtained from some particular prey type, or whether prey types exist that could expose sea otters to high levels of contaminants if a switch in diet were to occur. These analyses should include San Nicolas Island. Parts of the southern California bight contain high levels of organic contaminants, especially DDT and DDE. However, contaminants were not considered in the decision to translocate sea otters to San Nicolas Island, and no information has been obtained subsequently on the levels of these compounds that might occur there.

4.3.4 Analyze tissues for evidence of stress or disease.

In 1992, the National Wildlife Health Center began a coordinated necropsy program for southern sea otters. Since this program was started, the proportion of fresh carcasses for which cause of death could not be determined has decreased substantially, and a number of new diseases and pathogenic conditions have been identified. The California Marine Wildlife Veterinary Care and Research Center has become operational, participates in this program, and has expanded the program to include carcasses other than those that are very fresh, as well as carcasses removed from fishing gear. We and the Recovery Team believe that the coordinated necropsy program is one of the most important new developments for the southern sea otter. Therefore, the National Wildlife Health Center and the California Marine Wildlife Veterinary Care and Research Center should continue this program. At least 5 years of study will be needed to obtain adequate sample sizes. This program should expand to include comparable analyses of carcasses of other sea otter populations to determine whether the specific diseases and incidence of infectious disease are unique to the southern sea otter. A final report should be prepared discussing the findings, and if evidence is found that disease or stress is limiting the population growth rate, a plan to minimize the problem should be included. [Implementation of a plan to identify the cause(s) of the problems(s) will likely require a multi-agency effort (Environmental Protection Agency, Regional Water Quality Control Boards, other agencies, industry, watershed councils, environmental groups, etc.)] If the existing research and monitoring programs are judged inadequate, steps should be taken to refocus or augment them as necessary.

4.3.5 Determine the sources of disease agents and stress.

Necropsy analysis of carcasses and tissues provides the means to identify evidence of stress and disease, but the sources of stress and disease are not all likely to be elucidated by this method alone. We recognize that the understanding of infectious disease must include a broader consideration of potential ecological forcing factors. The analysis of infectious disease also should include a thorough consideration of potential forcing factors, such as environmental contaminants, treated waste water, harmful algal blooms, and other agents capable of suppressing the sea otter's immune system. An evaluation of potential and likely sources of stress and disease to southern sea otters should be compiled and reported.

4.3.6 Implement all reasonable and prudent measures to minimize factors causing stress or disease in the southern sea otter population.

Based on the above reports, we should coordinate with all pertinent agencies and organizations (California Department of Fish and Game, National Oceanic and Atmospheric Administration, Environmental Protection Agency, National Marine Fisheries Service, UC Davis, Oiled Wildlife Care Network, Monterey Bay Aquarium, etc.) to identify the proper procedures and implement the actions necessary to minimize those factors known or believed to have debilitating effects on the southern sea otter population.

Federal, State, and local programs aimed at determining the sources, levels, and effects of anthropogenic contaminants on the health of the marine ecosystem and its component parts should be evaluated to assure that they are capable of detecting and eliminating sources of contaminants and diseases that may be posing threats to sea otters, directly or indirectly through the marine food web of which sea otters are a part. This effort should begin with an effort simply to identify all such programs. We recognize that a comprehensive analysis of sources, levels, and effects of anthropogenic contaminants on the health of the marine ecosystem will be extremely challenging.

4.4 Evaluate the potential for habitat-related differences in growth rates between populations of sea otters.

The assumption that otters in central California are at maximal levels relative to what the environment will support, and that these densities are representative of maximal levels throughout central and northern California, is critical in predicting rates of recovery. The relationship between habitat and population demography needs to be evaluated to determine if habitat is affecting population growth rates. This effort should include two major dimensions: 1) an analysis of the habitat itself, and 2) an analysis of demographic, behavioral, and physiological parameters of sea otters that are relevant to the potential for resource limitation.

Habitat surveys should continue. Mapping of habitat types should evaluate supporting habitat for changes in types, abundance, distribution, and use (*e.g.* resting, haul out, feeding, breeding, natal area, peripheral feeding/resting areas, offshore areas) and changes in its estimated carrying capacity. Evidence gathered to date indicates that there are important interactions between sea otters and the habitats in which they live and forage; otter predation reduces many prey populations, including herbivorous invertebrates and/or species exploited in commercial and recreational fisheries. Social and economic consequences of this interaction are the primary societal barrier to the natural expansion of sea otters and recovery of the California population. Furthermore, food resources (including fluctuations in food availability from events such as El Niño) likely have important effects on the behavior and population status of sea otters. These interactions have been discovered and documented in northern populations through comparison of areas with and without sea otters, or between areas in which the density of sea otters varies. However, some of the proposed interactions, including effects on commercial and recreational fisheries, have been questioned because of the potentially confounding effects of other variables that may fortuitously co-vary with sea otter populations. It is possible to provide more compelling evidence for or against these proposed processes by observing systems through time with varying densities of sea otters. This kind of monitoring is being done at San Nicolas Island and elsewhere by conducting habitat surveys of particular areas through time, while at the same time studying population trends and the foraging behavior of sea otters. Taken together, these data will provide a record of how expanding sea otter populations influence shellfish populations and other components of the coastal ecosystem, and how the behavior and demography of sea otter populations co-vary with these environmental changes.

A final report, based on the findings of these research programs, should compare habitat quality among sections of the California coast and reach a conclusion concerning the adequacy of the hypothesis that habitat quality is constant in central and northern California and whether the population growth rate is affected by habitat parameters. Information from these studies should be analyzed and used in reevaluating recovery criteria.

4.5 Estimate effective population size of the southern sea otter population.

Estimating the size at which the southern sea otter population should be considered endangered requires an estimate of effective population size. The estimate of effective population size used in this recovery plan is based solely on theoretical calculations (Ralls *et al.* 1983). Thus, an empirical estimate of the effective population size of the population would be useful.

Data on microsatellites (highly variable nuclear markers) can be used to estimate the effective population size (see Schwartz *et al.* 1998 for a review of these methods). The temporal allele method is the most reliable method for estimating effective population size from DNA data (Waples 1989, Luikart *et al.* 1998). This method examines the change in allele frequencies across several generations. In small populations, genetic drift drastically changes allele frequencies, while in larger populations allele frequencies remain stable. By calculating the change in allele frequencies over several sea otter generations, we can back calculate the effective population size that drives the change. Recently, both Bayesian and maximum likelihood methods have been applied to the temporal allele technique, providing more precise and accurate measures of effective population size.

Tissue samples (hind flipper punches) from sea otters captured for the 1987 translocation are available. DNA from tissue samples from otters captured in other projects should be saved for an appropriate genetic comparison with these earlier samples at some future time.

5. Evaluate the translocation program in light of changed circumstances and determine whether one or more failure criteria have been met.

In August 1998, we held two public meetings to provide information on the status of the translocation program, identify alternatives to consider, and solicit general comments and recommendations. At these meetings, we announced that we would begin the process of evaluating failure criteria established for the translocation plan. The technical consultants group for the Recovery Team, composed of representatives from the fishery and environmental communities as well as State and Federal agencies, was expanded to assist with evaluating the translocation program.

In March 1999, a draft evaluation of the translocation program was distributed to interested parties. The draft document included the recommendation that we declare the translocation program a failure because fewer than 25 sea otters remained in the translocation zone and reasons for the translocated otters' emigration or mortality could not be identified and/or remedied. We received substantive comments from agencies and the public following release of the draft for review.

On July 27, 2000, we published a notice of intent to prepare a supplemental EIS on the southern sea otter translocation program (65 *FR* 46172). The need for a supplemental EIS is based on changed circumstances and new information that we have gained since the original EIS on the translocation of southern sea otters was prepared in 1985 and 1986 (published in 1987). We are currently preparing the draft supplemental EIS, and plan to release it for public comment in 2003. The draft evaluation of the translocation program released in March 1999 will be finalized following further opportunity for public participation in the decision-making process and completion of the EIS. After completion of the final supplemental EIS, a record of decision will be published in the *Federal Register*.

6. Improve captive sea otter management techniques.

Captive sea otter management techniques should be improved to 1) increase our ability to successfully breed sea otters should the need arise to take a more active role in captive propagation efforts (perhaps including the development of a husbandry manual); 2) ensure adequate genetic diversity in the captive population by conducting genetic studies to assess genetic variability in wild and captive sea otter populations (including the maintenance of a comprehensive stud book for all southern sea otters in captivity); and 3) facilitate various research needs such as research on basic nutritional requirements for both sexes and all age classes to assess possible nutritional stress, and research to improve the success of rehabilitation and reintroduction efforts (*e.g.* of previously stranded or oiled otters). We intend to complete an enhancement permit in conjunction with improvements in the captive management program.

7. Develop and implement a public education and outreach program.

A public education and outreach program should be created to enhance public understanding, respect, and concern for southern sea otters. The successful implementation of some recovery tasks for the southern sea otter may depend on the awareness, support, cooperation, and involvement of the public. The apparent role of sea otters as indicators of the health of nearshore marine ecosystems provides a unique opportunity to address the community ecology of sea otters in California and the ecosystem of which they are a part.

7.1 Develop and implement education and interpretation programs on southern sea otters and nearshore ecosystems.

Education and interpretation programs should be designed to reach a wide audience, including school-age children, recreationists, visitors, and community members. These programs should address southern sea otter community ecology, life history, former and current range, past and present threats, and recovery actions. Supporting materials may include videos, brochures, workbooks, interpretive displays, traveling educational boxes, art and drama materials (for schoolchildren), posters, etc.

7.2 Create opportunities for public involvement in the recovery of the southern sea otter and its associated ecosystems.

Some of the recovery actions outlined in this recovery plan will directly affect, or be affected by, human activities that affect the nearshore marine environment. It is therefore imperative to maximize opportunities wherever possible for the involvement of interested and affected parties in the implementation of recovery tasks, both to garner support for recovery actions and to promote better understanding and cooperation between different groups. Volunteer or paid opportunities and training should be provided and the unique skills of interested and affected parties utilized wherever possible in order to foster mutual understanding and to encourage concern for the southern sea otter and the threats to its survival.

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IV. Implementation Schedule

The following implementation schedule outlines actions and estimated costs for the recovery program. It is a guide for meeting the objectives discussed in the recovery section of this plan, and indicates task priorities, task descriptions, duration of tasks, responsible agencies, and estimated costs. These actions, when accomplished, should bring about the recovery of the southern sea otter and protect its habitat. As the estimated monetary needs for all parties involved in recovery are identified, this schedule reflects the total estimated financial requirements for the recovery of this species. Total costs for ongoing actions are estimated based on a hypothetical 20-year time to recovery; however, as noted above, a likely time to recovery cannot be projected because the population is currently not increasing and the reasons for the lack of increase have not yet been determined.

Tasks are arranged in priority order in the implementation schedule. The assigned priorities are defined as follows:

Priority 1–An action that must be taken to prevent extinction or to prevent the species from declining irreversibly in the foreseeable future.

Priority 2–An action that must be taken to prevent a significant decline in species population or habitat quality, or some other significant negative impact short of extinction.

Priority 3–All other actions necessary to meet the recovery objectives.

The following abbreviations are used in the Implementation Schedule:

Task Duration

Cont.–The action will be implemented continually once initiated.

Ongoing–The action is currently being implemented and will continue until no longer necessary for recovery.

Responsible Party

*	Lead Agency
BRD	U.S. Geological Survey, Biological Resources Division
CDFG	California Department of Fish and Game
CDFG-MWVCRC	California Department of Fish and Game–Marine Wildlife Veterinary Care and Research Center
CDFG-OSPR	California Department of Fish and Game–Office of Spill Prevention and Response
EPA	U.S. Environmental Protection Agency

FWS	U.S. Fish and Wildlife Service
MBA	Monterey Bay Aquarium
NMFS-SWC	National Marine Fisheries Service–Southwest Center
NMFS-SWR	National Marine Fisheries Service–Southwest Region
MMS	U.S. Minerals Management Service
NOAA	National Oceanic and Atmospheric Administration, National Marine Sanctuaries
NPS	National Park Service
Other	Other parties yet to be determined
OWCN	U.C. Davis, Oiled Wildlife Care Network
USCG	U.S. Coast Guard

Time Period

FY	Federal fiscal year, from October 1 through September 30

Costs

TBD	Costs yet to be determined

Note: Costs of minimizing intentional take (Task 3.2) are generally embedded in law enforcement expenses and, because occurrence of intentional take appears to be uncommon and sporadic, are difficult to estimate in advance. Costs of identifying and minimizing disease and stress factors (Tasks 4.3.5 and 4.3.6) depend on results of future studies. Outreach expenses (Tasks 7.1 and 7.2) have largely not yet been identified pending development of a general public education and outreach program.

Southern Sea Otter Recovery Plan Implementation Schedule

Priority Number	Task Number	Task Description	Task Duration (years)	Responsible Party	Total Costs $1,000s[1]	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008
1	1.1	Monitor abundance and distribution, and determine if current estimates are negatively biased	Ongoing[3]	BRD* FWS CDFG MBA	360.0 140.0 200.0 100.0	18.0 7.0 10.0 5.0	18.0 7.0 10.0 5.0	18.0 7.0 10.0 5.0	18.0 7.0 10.0 5.0	18.0 7.0 10.0 5.0
1	1.2	Evaluate causes of otter mortality	Ongoing[3]	BRD FWS CDFG* NMFS-SWC MBA	700.0 140.0 1190.0 TBD 60.0	35.0 7.0 55.0 3.0	35.0 7.0 55.0 3.0	35.0 7.0 60.0 3.0	35.0 7.0 60.0 3.0	35.0 7.0 60.0 3.0
1	2.1.1	Implement and monitor USCG vessel management plan	Ongoing[3]	USCG* NOAA FWS	200.0 140.0 140.0	10.0 7.0 7.0	10.0 7.0 7.0	10.0 7.0 7.0	10.0 7.0 7.0	10.0 7.0 7.0
1	3.1.1	Monitor incidental take in commercial fisheries	2	FWS BRD CDFG NMFS-SWR*	TBD TBD TBD TBD					
1	3.1.2	Evaluate the effectiveness of fishing regulations for preventing sea otter take	1	FWS CDFG* NMFS-SWC	3.0 3.0 3.0	3.0 3.0 3.0				
1	3.1.3	Evaluate the potential for incidental take in trap/pot fisheries	1	FWS BRD* MBA	8.0 8.0 10.0	8.0 8.0 10.0				
1	3.1.4	Determine and take possible steps to reduce or eliminate sea otter mortality incidental to fisheries.	1	FWS CDFG* NMFS-SWC	3.0 3.0 3.0	3.0 3.0 3.0				

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Priority Number	Task Number	Task Description	Task Duration (years)	Responsible Party	Total Costs $1,000s[1]	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008
1	3.2	Minimize intentional take	Ongoing[3]	FWS BRD CDFG* NMFS-SWR	TBD TBD TBD TBD					
1	4.1	Estimate the current probability of the population being below 1,850 over the next 10 years. Incorporate this analysis into delisting criteria.	2-3 months	FWS	15.0	15.0				
1	4.2	Evaluate differences in life history parameters of sea otters	5	FWS BRD* MBA	5.0 1,850.0 300.0	1.0 400.0 60.0	1.0 400.0 60.0	1.0 350.0 60.0	1.0 350.0 60.0	1.0 350.0 60.0
1	4.3.2	Determine sources of environmental contaminants	2	FWS CDFG* EPA NOAA MBA	4.0 225.0 12.0 12.0 6.0			2.0 75.0 6.0 6.0 3.0	2.0 150.0 6.0 6.0 3.0	
1	4.3.3	Determine contaminant levels in sea otter prey and habitat	2	NOAA CDFG*	225.0 225.0		75.0 75.0	150.0 150.0		
1	4.3.4	Collect and analyze tissues for evidence of stress or disease	5	BRD FWS CDFG* MBA	500.0 5.0 1,000.0 50.0	100.0 1.0 200.0 10.0	100.0 1.0 200.0 10.0	100.0 1.0 200.0 10.0	100.0 1.0 200.0 10.0	100.0 1.0 200.0 10.0
1	4.3.5	Determine sources of disease agents and stress	Unknown	FWS CDFG* NOAA EPA MBA	TBD TBD TBD TBD TBD					

Priority Number	Task Number	Task Description	Task Duration (years)	Responsible Party	Total Costs $1,000s[1]	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008
1	4.3.6	Minimize factors causing stress and disease	Unknown	FWS CDFG* NOAA EPA	TBD TBD TBD TBD					
1	4.5	Estimate effective population size of the southern sea otter population.	1	FWS	60.0 (lab work only)		60.0			
1	5	Evaluate the translocation program in light of changed circumstances and determine whether one or more failure criteria have been met	1	FWS* BRD CDFG	200.00 5.0 5.0	200.0 5.0 5.0				
2	2.1.2	Assess current risk of tanker accidents and other possible sources of oil spills, including off-shore oil platforms, pipelines, and marine terminals	1	FWS USCG CDFG-OSPR* MMS	3.0 3.0 75.0 TBD	3.0 3.0 75.0				
2	2.2	Implement an oil spill contingency plan that includes a sea otter response plan.	Ongoing[3]	FWS CDFG-OSPR* MBA	22.0 60.0 20.0	2.0 3.0 1.0	2.0 3.0 1.0	1.0 3.0 1.0	1.0 3.0 1.0	1.0 3.0 1.0
2	4.3.1	Analyze tissues from southern sea otters for environmental contaminants and archive tissues for future analysis	Ongoing[3]	NBS FWS CDFG* MBA	40.0 40.0 40.0 40.0	2.0 2.0 2.0 2.0	2.0 2.0 2.0 2.0	2.0 2.0 2.0 2.0	2.0 2.0 2.0 2.0	2.0 2.0 2.0 2.0
3	1.3	Develop and implement a post-delisting monitoring plan	TBD[2] (develop before delisting)	BRD FWS* CDFG MBA	TBD					
3	4.4	Evaluate the potential for habitat related differences in growth rates between populations of sea otters	5	BRD* FWS MBA	625.0 5.0 50.0	125.0 1.0 10.0	125.0 1.0 10.0	125.0 1.0 10.0	125.0 1.0 10.0	125.0 1.0 10.0

Priority Number	Task Number	Task Description	Task Duration (years)	Responsible Party	Total Costs $1,000s[1]	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008
3	6	Improve captive sea otter management techniques	5	FWS MBA*& Others CDFG BRD	17.0 250.0 15.0 15.0	5.0 50.0 3.0 3.0	3.0 50.0 3.0 3.0	3.0 50.0 3.0 3.0	3.0 50.0 3.0 3.0	3.0 50.0 3.0 3.0
3	7.1	Develop and implement education and interpretation programs on southern sea otters and nearshore ecosystems.	Ongoing[3]	FWS MBA CDFG NOAA NPS Other	TBD 1000.0 TBD TBD TBD TBD	50.0	50.0	50.0	50.0	50.0
3	7.2	Create opportunities for public involvement in the recovery of the southern sea otter and its associated ecosystems.	Ongoing[3]	FWS MBA CDFG NOAA NPS Other	TBD TBD TBD TBD TBD TBD					
		Estimated Total Costs:			7,848+	1,547+	1,405+	1,541+	1,316+	1,149+

1 Total costs for ongoing tasks are estimated for a 20 year period.

2 Continued implementation of task expected to be necessary after delisting.

3 Task expected to be necessary until delisting of species.

V. Appendices

Appendix A: Biennial Survey Results

Range and population expansion of the sea otter along the California coast, 1914 to 1999. Population estimates and amount of occupied range from 1914 to 1980 are from the original southern sea otter Recovery Plan. Population information from 1982 to 1999 is from spring surveys of the sea otter population in California, north of Point Conception.

Year	Range (km)	# Independent otters	# pups	Total
1914	11*			50
1938	43			310
1947	74			530
1950	89			660
1955	108			800
1957	125			880
1959	137			1,050
1963	152			1,190
1966	158			1,260
1969	177			1,390
1972	192			1,530
1973	244			1,720
1974	255			1,730
1975	263			?
1976	279			1,789
1977	293			?
1978	293			?
1979	299			1443**
1980	312			?
1982		1,124	222	1,346

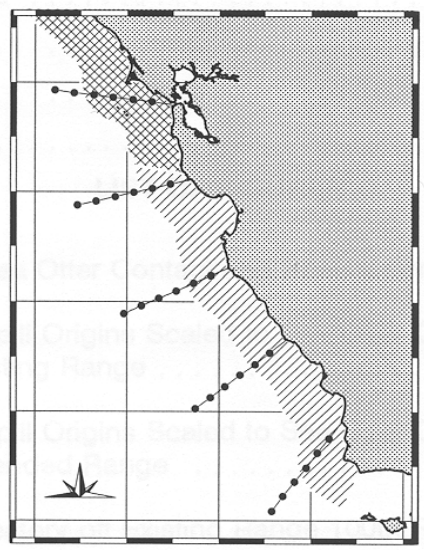
Year	**Range (km)**	**# Independent otters**	**# pups**	**Total**
1983		1,156	121	1,277
1984		1,180	123	1,303
1985		1,119	242	1,361
1986		1,358	228	1,586
1987		1,435	226	1,661
1988		1,504	221	1,725
1989		1,571	285	1,856
1990		1,466	214	1,680
1991		1,700	241	1,941
1992		1,810	291	2,101
1993		2,022	217	2,239
1994		2,076	283	2,359
1995		2,095	282	2,377
1996		1,963	315	2,278
1997		1,919	310	2,229
1998		1,955	159	2,114
1999		1,858	232	2,090
2000		2,053	264	2,317
2001		1,863	298	2,161
2002		1,846	293	2,139

* No records available, estimates are rough approximations.
** Survey conducted under poor weather conditions.

Appendix B: Potential Impacts of Oil Spills on the Southern Sea Otter Population

FINAL REPORT

Potential Impacts of Oil Spills on the Southern Sea Otter Population



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INTRODUCTION

The purpose of this study was to assess potential impacts on the southern sea otter population from large oil spills that might occur off the California coast. This was done by running computer simulations of the movement and spread of oil from spills varying from 31,250 bbl to 1,000,000 bbl. In initial model runs, simulated spills were released from randomly selected sites within 25 nautical miles (nmi) of the existing sea otter range and a hypothetical future range along the coast of northern California. Results of model runs were analyzed to determine where oil spills present the greatest risk to populations of sea otters and the influence of spill size on number of sea otters contacted. To examine the effect of distance from shore, a second set of simulations were made in which spills were released at 10 nmi increments from land.

Initially, the model was run with 100 simulations at randomly selected sites and wind conditions to determine rank-order of results and identify the spill location and wind conditions affecting the greatest number of sea otters. These simulations were of a 250,000 bbl spill released at randomly selected sites within 25 nmi of shore. The 250,000 bbl size was approximately that of the *Exxon Valdez* spill and was used as a basis for determining "reasonable worst case" for the population of southern sea otters. The single simulation contacting the greatest number of sea otters (i.e., the 100th percentile simulation) was, by definition, the worst case in these model runs. Although such a spill is clearly possible, it may not be the best example of a reasonable worst case spill event. Reasonable worst case has no formal definition but rather depends on consensus. To encompass varying opinions, the 90th percentile was chosen as a lower bound on reasonable worst case. Both the 100th and 90th percentile simulations were modeled in detail for the existing range; only the 100th percentile spill was modeled in detail for the hypothetical northern California range. These three simulations are referred as Detailed Scenarios and discussed below.

Lastly, the model was run to determine the probability distribution of number of sea otters contacted by simulated spills, where the spill size was provided by randomly sampling from the size distribution of past spills. These probabilities were conditional on the occurrence of oil spills. To provide a best estimate of probabilities that sea otters will actually be contacted by oil spills, the expectation of number of sea otters contacted was multiplied by the expectation of oil spills. In any given year the expectation of oil spills is relatively small; therefore a reasonable time-frame must be chosen for assessing potential impacts. For this analysis, final probabilities of number of sea otters contacted by oil spills were calculated for a 30-year period.

METHODS

The computer model OSRISK was used to perform the spill trajectory analysis. Versions of this model have been developed for hindcasting real-time spills (Ford 1986), training spill-response personnel (the spill model OCCUR prepared for the Clean Bay Cooperative), conducting risk analyses (Chambers Group, Inc. and Ecological Consulting, Inc., for the California State Lands Commission; Unocal EIR), and helping define tanker transport routes that minimized the risk of oil contact with sensitive resources (Ford et al. 1990). OSRISK accepts wind and surface current information from external sources and combines them with geographic data describing animal distribution and oil spill behavior. The model simulates an oil spill occurring under a specific set of conditions, taking into account as needed the time of year, wind conditions, tidal state, spill volume, chemical composition, the extent of tidally inundated substrates, and other factors. The spill is represented as a cluster of independently moving points (Lagrangian Elements or LEs), each representing a fraction of the entire spill volume.

Hydrological data were taken from the Minerals Management Service's curvilinear surface current grid for the Pacific coast prepared by Dynalysis of Princeton. The finite element mesh forming the grid is composed of 1,200 quadrilateral elements roughly paralleling the outer coast and decreasing in size along the shoreward edge of the grid. The data used by OSRISK were seasonally averaged surface current vectors at each node. At each 2-hour time step, OSRISK located the rectangular element containing a given LE. The surface current vector at the location of the LE was estimated as the inverse distance weighted average of the current vector at each of the four adjacent nodes. OSRISK uses sequences of real-time winds to generate a time-varying wind field. At the position of each LE at each 2-hour time step, the wind vector was calculated as the inverse distance weighted mean of the wind speeds and directions recorded at each of several NOAA meteorological buoys. Crude oil was assumed to be persistent; that is, undergoing little or no decrease in volume due to evaporation. Each LE was tracked for 21 days, until beached, or until out of the model domain.

The area affected by an oil spill varies with the volume of the spill, the age of the spill, and the wind and current conditions that prevail during the course of the spill. OSRISK simulates the process of spreading by adding a random diffusive component to the advection induced by winds and currents at each model time step. The larger the random factor and larger the number of LEs used to simulate the slick, the more rapidly the slick expands and the more extensive the region impacted by the slick. The spreading rate of the model slicks was calibrated by selecting a random diffusive factor and number of LEs such that the area defined by placing a 5-km radius buffer around each LE matched the observed regression of the areal extent of real slicks of a given volume after 7 days (Ford and Casey 1985).

Baseline model runs consisted of 200 computer simulations of a 250,000 bbl oil spill for the existing sea otter range and another 200 simulations for a hypothetical northern California range. The size of the simulated spill (250,000 bbl) was chosen to approximate the *Exxon Valdez* spill. The release sites were determined using a random-number generator to select points within a polygon extending 25 nm seaward from Pt. Arena in the north to Pt. Conception in the south. Simulations consisted of the release of 100 LEs, each representing 2,500 bbl of oil, at a randomly selected time of year. The movement of each LE by winds and currents was modeled within a GIS that included a detailed digital shoreline and the position of each sea otter or group from the USFWS spring and fall 1992 censuses and from a hypothetical distribution of sea otters created by the USFWS for the northern California coast. If any LE passed within 5 km of the observed position of a sea otter or group of sea otters, the group was assumed to have been contacted by the slick. The 5 km effective radius was chosen as an approximation of the length of coastline that would be affected by 2,500 bbl of oil. (The model is relatively insensitive to this parameter: a 100% increase in the size of the effective area increased the number of contacts by only 3.6%.)

Detailed scenarios of oil movement and number of sea otters contacted over time were prepared for the 100th and 90th percentile spills affecting the existing range and the 100th percentile for the hypothetical northern California range. To provide greater spatial resolution, these were simulated using the same spill site and winds regime but releasing 2,500 LEs each representing 100 bbl of oil. Mortality of sea otters contacted in these scenarios was estimated from the relationship provided by Brody (1992). This relationship describes survival of sea otters as a function of distance from the spill origin from data collected in Alaska waters following the *Exxon Valdez* oil spill.

The relationship between spill volume and the number of sea otters contacted was examined by running the model as above, but modifying the spill volume. Two hundred spills, each consisting of 100 LEs, were simulated for each of the following spill volumes:

31,250 bbl
62,500 bbl
125,000 bbl
500,000 bbl
1,000,000 bbl

All simulations with random selection of release sites were made within 25 nmi of shore. To further examine the relationship between distance from shore and the number of sea otters contacted, the model domain was extended to 60 nmi. Simulated spills were released at 10 nmi increments along five lines orthogonal to the coastline. A total of 200 model spills, each consisting of 100 LEs, were released from each of six stations along these lines. Spill size and times of year were the same as in baseline model runs; however, release sites were predetermined rather than randomly selected so as to simplify analysis.

Final probabilities of number of sea otters in the existing range that might be contacted by oil spills over a 30-year period were calculated from the conditional probabilities resulting from the trajectory modeling described above and the expectation of oil spills. The expectation of oil spills equal to or greater than 1,000 bbl was taken from the analysis of 1974 through 1985 data by Anderson and LaBelle (1990). This occurrence rate of 0.9 spills per 1 billion bbl of oil transported is virtually unchanged from that of an earlier study (Lanfear and Amstutz 1983). It differs from the earlier study in that findings are based on a larger and more recent data base of worldwide spills. The exposure variable of volume of oil transported along the California coast was estimated for each of four routes from data assembled for the Western States Petroleum Association by DNA Associates (1993). The four routes used by tankers along the California coast are North Coast, Alaska and Overseas, South Coast, and Estero Bay. The North Coast route included all transport to or from Humboldt Bay, Oregon, Washington, and Canada past the coast from the entrance to San Francisco Bay to Point Arena. Transport of oil and products was assumed to use the northwest-southeast lanes of the San Francisco Traffic Separation Scheme (TSS). The Alaska and Overseas Route included all oil and products transported to or from San Francisco Bay and Alaska, Asia, Hawaii, Mexico, Panama, and South America. This oil was assumed to be transported exclusively along the east-west lanes of the San Francisco TSS. The South Coast Route included transport to or from San Francisco Bay, Estero Bay, and Los Angeles/Long Beach. The Estero Bay Route included only the volume of oil transported along a spur from the South Coast Route; oil from Estero Bay is transported by tanker and barge to Los Angeles/Long Beach and by tanker to Oregon and Washington.

The 1992 volumes from DNA Associates (1993) along these routes were assumed to be representative of the oil transport scenario of the next 30 years; thus the 1992 volumes were multiplied by 30 to arrive at a total projected volume transported along these routes over a 30 year period. The projected volume was then multiplied by the occurrence rate of 0.9 spills greater than 1,000 bbl per billion bbl of oil transported (from Anderson and LaBelle 1990) to arrive at an expected number of spills along each route over a 30-year period. The likelihood of spills was assumed to be uniformly distributed along each of these routes. However, because only 15.4% of the North Coast Route extends south of Point Arena, we multiplied the expected number of spills for this route by 0.154 to estimate the expectation of oil spills. Because most spills occur within 50 miles from land (Card et al. 1975), for the Alaska and Overseas Route, we assumed that one-half of spills would occur in the approaches to San Francisco Bay; the remainder was assumed to occur in the approaches to Prince William Sound, or Asian, Pacific, or other foreign ports. Thus, the expected number of spills for the Alaska and Overseas Route was multiplied by 0.5.

The steps outlined above provide an expectation of oil spills equal to or greater than 1,000 bbl along these routes. Small spills are more likely to occur than large ones, and the size of a spill directly affects the number of sea otters contacted. Therefore, a frequency distribution of spill size was constructed from the historical database used by Anderson and LaBelle (1990) and randomly sampled for each simulation. The database included spills that are larger than might reasonably be expected to occur along the California coast. Thus, the frequency distribution of spill size was truncated at 350,000 bbl. This truncation volume was determined based on the capacity of tankers using the four routes. Fully laden tankers transiting past the sea otter range along the South Coast Route carry 73,000 bbl to 350,000 bbl (from analysis of the U. S. Coast Guard 1982 Port Access Route Study). The Alaska and Overseas route into San Francisco Bay may include larger tankers; however, water depth generally limits tankers to 350,000 bbl capacity or less (Chambers Group, Inc. 1994).

RESULTS AND DISCUSSION

Baseline Model Runs

Baseline model runs consisted of 200 simulations released at randomly selected sites, and were generated for both the existing main sea otter range and the extended sea otter range. The results of these simulations are shown in Figure 1. For the existing sea otter range, the 50th, 90th, and 95th percentiles were 123, 857, and 978 sea otters contacted by oil, respectively. In other words, in 50% of the simulations, up to 123 sea otters were contacted, in 90% of the simulations, up to 857 sea otters were contacted, and so on. Comparable values for the extended sea otter range were 672, 1658, and 2,132 sea otters contacted by oil. The number of contacts in the extended range tends to be greater than in the existing range because it is assumed that the extended range will ultimately contain a larger number of sea otters than the existing range.

The origins of the spills modeled at randomly selected sites are shown in Figures 2a and 2b for the existing and extended sea otter ranges. The size of the circles representing the origin of each spill are scaled so that spills resulting in a large number of contacts are represented by larger circles, and spills resulting in few contacts are represented by smaller circles. For the existing sea otter range, spills occurring north of Point Reyes did not result in large numbers of contacts. In this northern area, simulated oil spills released farther offshore resulted in more contacts in the existing range than spills occurring closer to shore; inshore spills are beached or dissipated before drifting sufficiently far to the south to reach more densely occupied portions of the existing sea otter range. The greatest risk to the existing sea otter range results from spills originating between Point Reyes and Lopez Point. Within this area, spills originating in the region from Half Moon Bay to Monterey Bay result in the greatest number of contacts to sea otters.

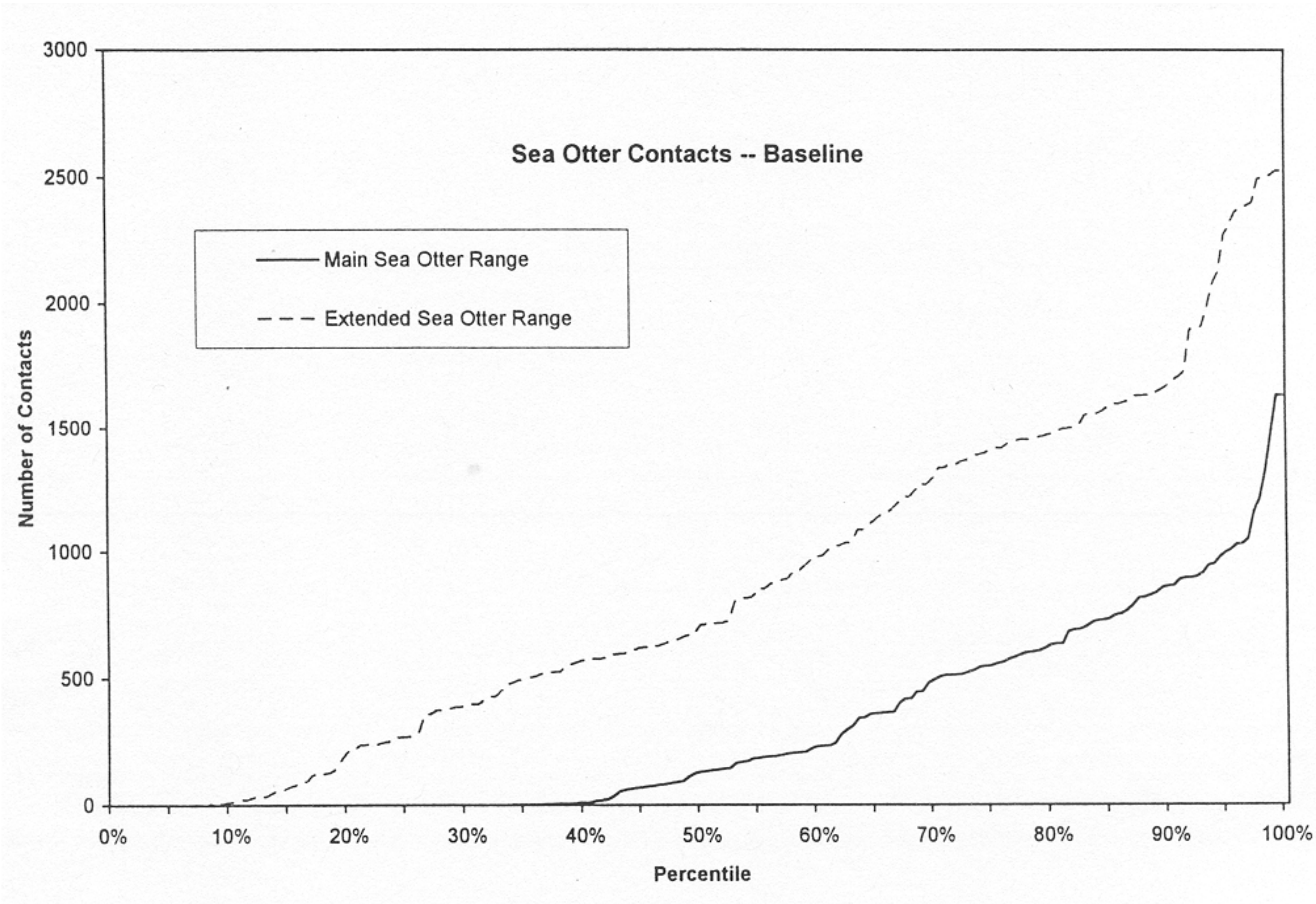

Figure 1. Sea otter contacts and rank-order percentiles from baseline model runs.

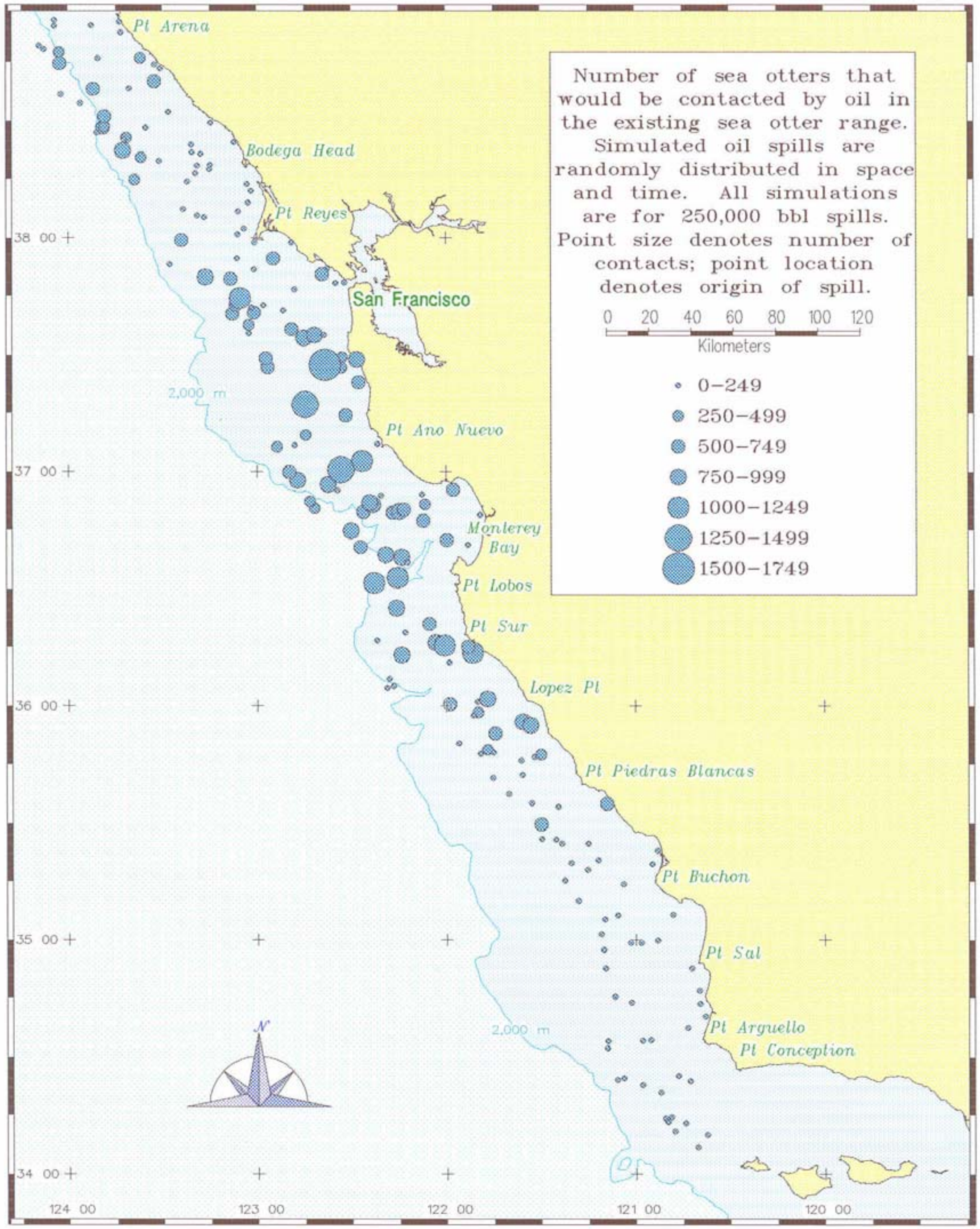

Figure 2a. Spill origins scaled to number of sea otters contacted in existing range from baseline model runs.

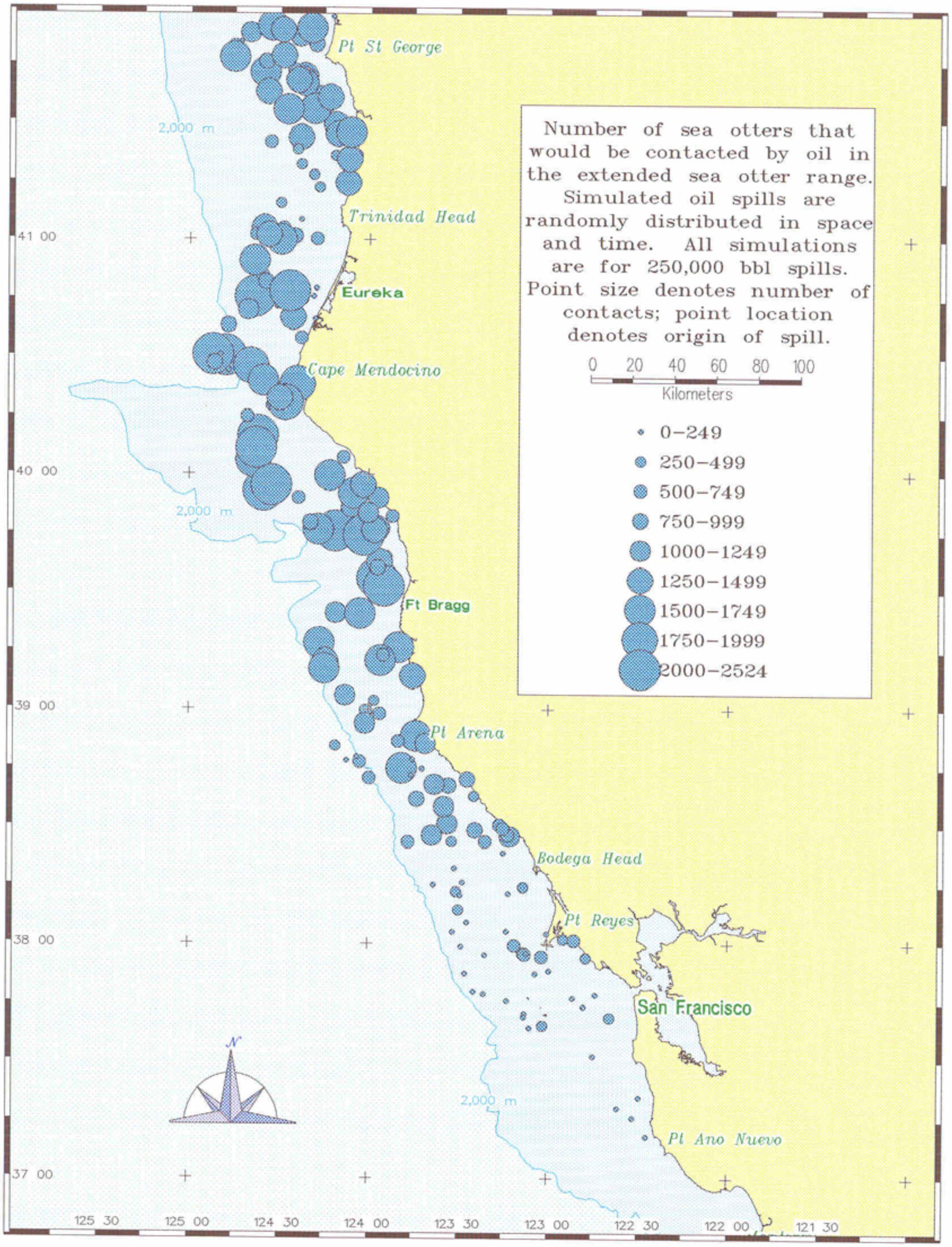

Figure 2b. Spill origins scaled to number of sea otters contacted in extended range from baseline model runs.

In the extended range, the number of sea otters likely to be contacted by a spill occurring between the California/Oregon border and Bodega Head is relatively high. (Although we did not model spills occurring north of the State boundary, spills originating off Oregon could also reach the extended sea otter range). The greatest risk would result from spills originating in the area from Eureka to Ft. Bragg. Spills south of Bodega Head do not represent a major threat to the extended sea otter range. Further, it appears unlikely that a spill could occur that would have a major impact on both the existing and the extended sea otter ranges. In general, the impact of spills occurring north of Bodega head would have little impact on the sea otters in the existing range; spills occurring south of Bodega Head would be unlikely to have a major impact on sea otters in the extended range.

Detailed Scenarios

Three oil spill scenarios were chosen to model impacts of an *Exxon Valdez*-size spill on the existing sea otter range and on a hypothetical range representing a possible future distribution of sea otters along the northern California coast. Slicks produced by simulated spills were modeled as uncontained and freely-drifting, and not acted upon by dispersants or other methods that might be used to reduce impacts. Each scenario simulated a release of 250,000 bbl of oil, but differed in the location of the release site and in the winds and currents moving oil slicks. Both 100th percentile worst case and 90th percentile scenarios were modeled in detail for the existing range, assuming that a "reasonable" worst case spill falls somewhere in between these percentiles. For the expanded range along the northern California coast, only the worst case spill was used.

Estimates of mortality of sea otters were determined from a relationship of survival of sea otters as a function of distance from the spill origin (Brody 1992). The basis for this relationship was the capture database of sea otters in Alaska following the *Exxon Valdez* oil spill. The relationship assumes that survival of captured oiled sea otters is representative of a population of oiled animals observed but not removed from their con- taminated habitat. It seems likely that many sea otters left to their fate would become additionally oiled over time until they ultimately died of exposure. In the absence of substantiation, the estimates of mortality derived from this relationship should be viewed as minimum values.

Existing Range. The 100th percentile worst case scenario simulated a spill 36 km (19.5 nmi) west of Point Ano Nuevo with oil driven by real-time winds recorded from March 4 through 25, 1991. Over this three-week period, northwest winds were interrupted repeatedly by the passage of storms. South and southwest winds associated with these low-pressure cells slowed southward movement of the slick. Contact with sea otter habitat first occurred six days following the release when oil beached near Cypress Point and Point Lobos (Figure 3). Oil continued to enter sea otter habitat over the next three days under variable west and northwest winds to about 20 kts, and resulted in heavy contamination of nearshore waters to about Pfeiffer Point. The main body of the slick resumed its southward drift on day 9 after the spill under northwest winds of 20-30 kts, sparing parts of the sea otter range between Pfeiffer Point and Point Lopez. On day 12, south, southwest, and west winds of 20 kts or more again pushed oil toward shore, initially resulting in heavy oiling of sea otter habitat from Cape San Martin to about San Simeon Point. Over the subsequent four days, variable winds kept oil close to shore, first spreading northward to Lopez Point and then southward to Point Sal. By day 17, northwest winds of 15-25 kts resumed and oil was driven southward. Oil not yet beached rounded Point Conception by about day 20, and slicks became increasingly fragmented as oil drifted into the Santa Barbara Channel.

During this 100th percentile worst case spill episode, 1,820 southern sea otters were contacted by oil. The greatest number were contacted from day 6 through day 12, when most of the sea otter range from Cypress Point to San Simeon Point was extensively oiled (Figure 4; Table 1). Applying the relationship of sea otter survival to distance from the spill origin (Brody 1992), mortality from this spill scenario was estimated to be 777 sea otters (37% of the spring 1992 population). In the heavily contaminated portions of the coast from Cypress Point to Pfeiffer Point, the local population suffered mortality of about 55%, while mortality in habitat from Cape San Martin to San Simeon Point, also subject to heavy oiling, was 36% or less.

The 90th percentile worst case scenario was a spill released 20 km (11 nmi) west of San Gregorio Beach (San Mateo County) and about 36 km (19.5 nmi) northwest of Point Ano Nuevo. The simulated spill was driven by real-time winds of August 11 through 31, 1990. Initial contact with sea otter habitat from Pescadero Point to Point Ano Nuevo occurred on the day after release (Figure 5). The oil slick moved along the shore under northwest winds of 15-20 kts, contacting sea otter habitat from Sand Hill Bluff to Point Santa Cruz two to three days after the spill; sea otter habitat near Soquel Point received only light oiling. By four to five days following the release, oil had spread across Monterey Bay resulting in heavy contamination from Moss Landing Harbor to Point Lobos. Five to six days following the spill, oil drifted south in a compact 10 km wide slick contacting sea otter habitat to about Pfeiffer Point. The slick then moved 3-5 km offshore, still remaining somewhat compact in the light winds and seas, and next contacted shore in the vicinity of Lopez Point about 13 days after the spill. Under the influence of variable winds from the south and west, oil continued to contact sea otter habitat from Lopez Point to Cape San Martin until about day 17, and thereafter drifted offshore leaving most of the range south of Point Piedras Blancas untouched.

In the 90th percentile spill scenario, oil contacted 881 sea otters. The greatest number of sea otters were contacted along the Monterey Peninsula and southward to Point Sur on days four and five following the spill (Figure 6; Table 2). Applying the relationship of sea otter survival to distance from the spill origin (Brody 1992), mortality from the 90th percentile spill scenario was estimated to be 456 sea otters (27% of the fall 1992 population). Mortality north of Point Santa Cruz was about 75% of numbers contacted, declining with distance to 56% mortality from Monterey Peninsula to Pfeiffer Point, and 39% mortality from Lopez Point to about Point Piedras Blancas.

Northern California Extended Range. The 100th percentile scenario was an oil spill released 15 km (8.2 nm) north of Cape Mendocino and 14 km (7.6 nm) off False Cape, the nearest land. Real-time winds driving the movement of oil were taken from May 11 through June 1, 1990. First contact with sea otter habitat occurred within 24 hours of the release and contaminated nearshore waters and the shoreline from Cape Mendocino to Punta Gorda (Figure 7). Over the first two days following the spill, the slick contacted shore to about Big Flat Creek and then moved 10 km offshore, well beyond sea otter habitat. By day 5, oil again moved toward shore and contaminated sea otter habitat from Cape Vizcaino to Point Arena. Thereafter, oil drifted south and did not again contact sea otter habitat until about day 9 when, under the influence of southwest winds to 20 kts, it swept along the coast of Point Reyes. From days 10 through 18, under south, southwest, and west winds to about 25 kts, oil remained predominantly within the Gulf of the Farallones. Contact with sea otter habitat was again made on days 19 through 21 when oil beached along the shore in Marin and San Francisco Counties.

The 100th percentile spill scenario off the northern California coast contacted 2,018 sea otters in the hypothetical extended range. The greatest number were contacted in the first seven days after the release when oil spread from Cape Mendocino to nearly Point Delgada and from Cape Vizcaino to Point Arena (Figure 8; Table 3). Applying the relationship of sea otter survival to distance from the spill origin (Brody 1992), mortality from this spill scenario was estimated to be 927 sea otters (20% of the northern California population). In the portion of the expanded range north of Point Arena, mortality was 50% of numbers contacted. Mortality of sea otters along the mainland shore south of Point Reyes was 28% of numbers contacted.

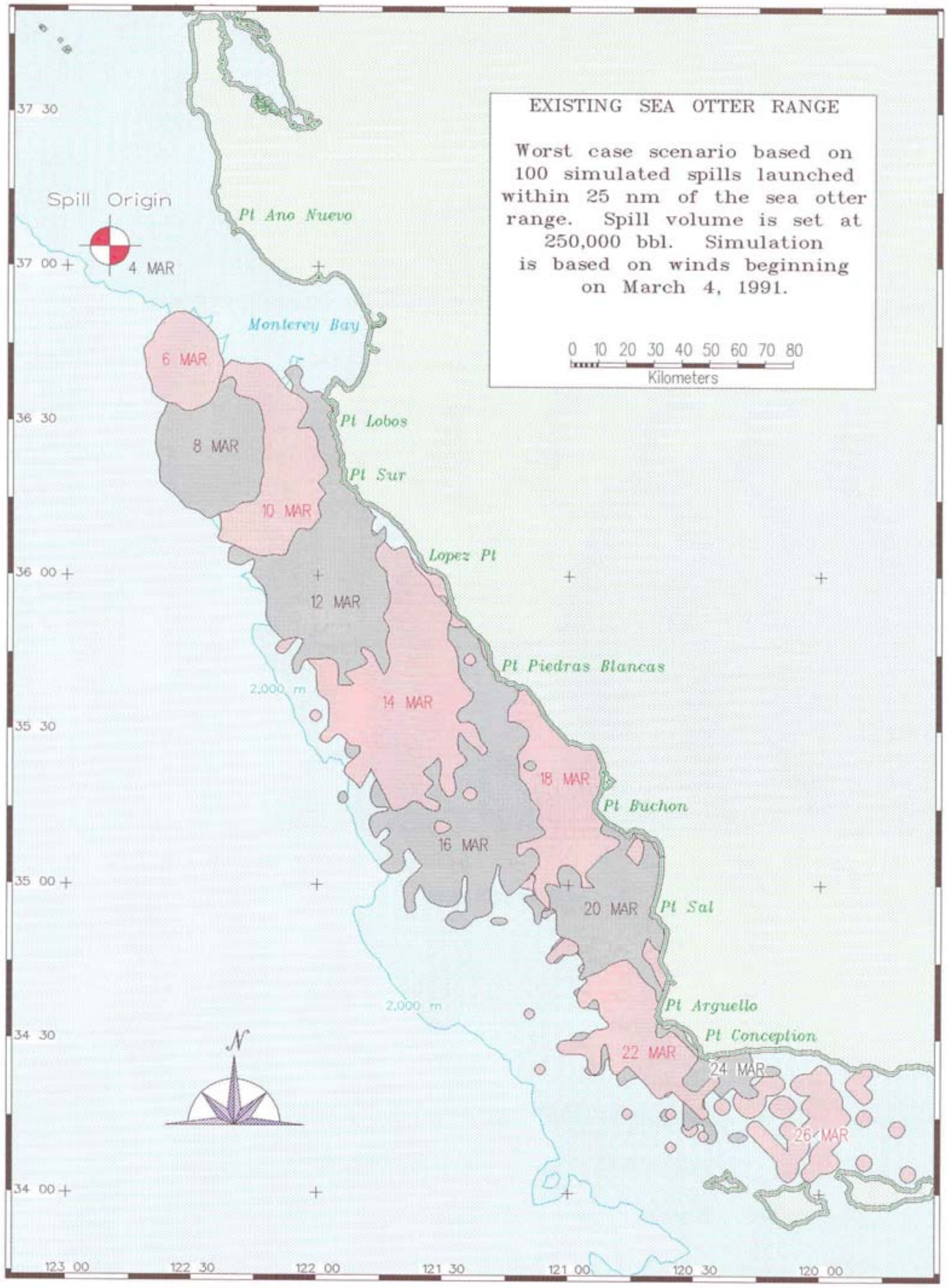

Figure 3. Trajectory of a simulated *Exxon Valdez*-size oil spill off the existing sea otter range. This simulation was the 100th ranking case out of 100 such spills launched within 25 nm of the coast. Alternating red and gray areas show the position of the slick through time.

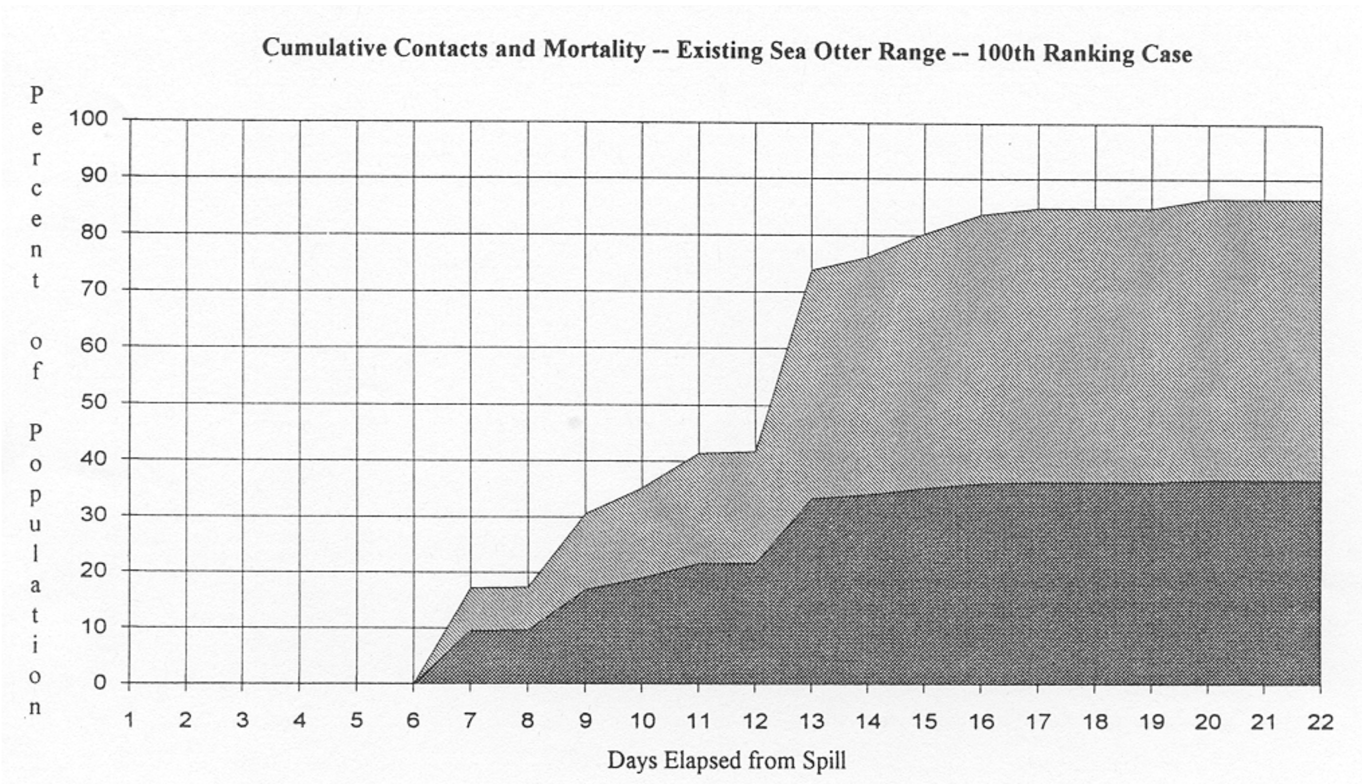

Figure 4. Cumulative percent of the total population in the existing sea otter range that would have been contacted or killed by an oil spill simulation. This simulation was the 100th ranking case out of 100 simulations of *Exxon Valdez*-size spills launched within 25 nm of the sea otter range. Light stippled area represents cumulative contacts, dark area represents estimated direct mortality.

Table 1. Existing Range: Number of southern sea otters contacted and estimated mortality resulting from 100th percentile worst case oil spill scenario.

Day	Number Contacted	Mortality [a]	Cumulative Contacted	Cumulative Mortality
0	0	0	0	0
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0
5	0	0	0	0
6	362	202	362	202
7	4	2	366	204
8	277	152	643	356
9	98	45	741	401
10	129	54	870	455
11	9	3	879	458
12	673	245	1552	703
13	48	14	1600	717
14	87	25	1687	742
15	72	19	1759	761
16	25	6	1784	767
17	0	0	1784	767
18	0	0	1784	767
19	36	10	1820	777
20	0	0	1820	777
21	0	0	1820	777

[a] Mortality calculated using the relationship of sea otter survival and distance from the spill origin (Brody 1992); it is assumed that this number of sea otters will die, among those contacted, regardless of number of days of exposure. Calculations assume no mitigation of impacts by rescue and rehabilitation of sea otters.

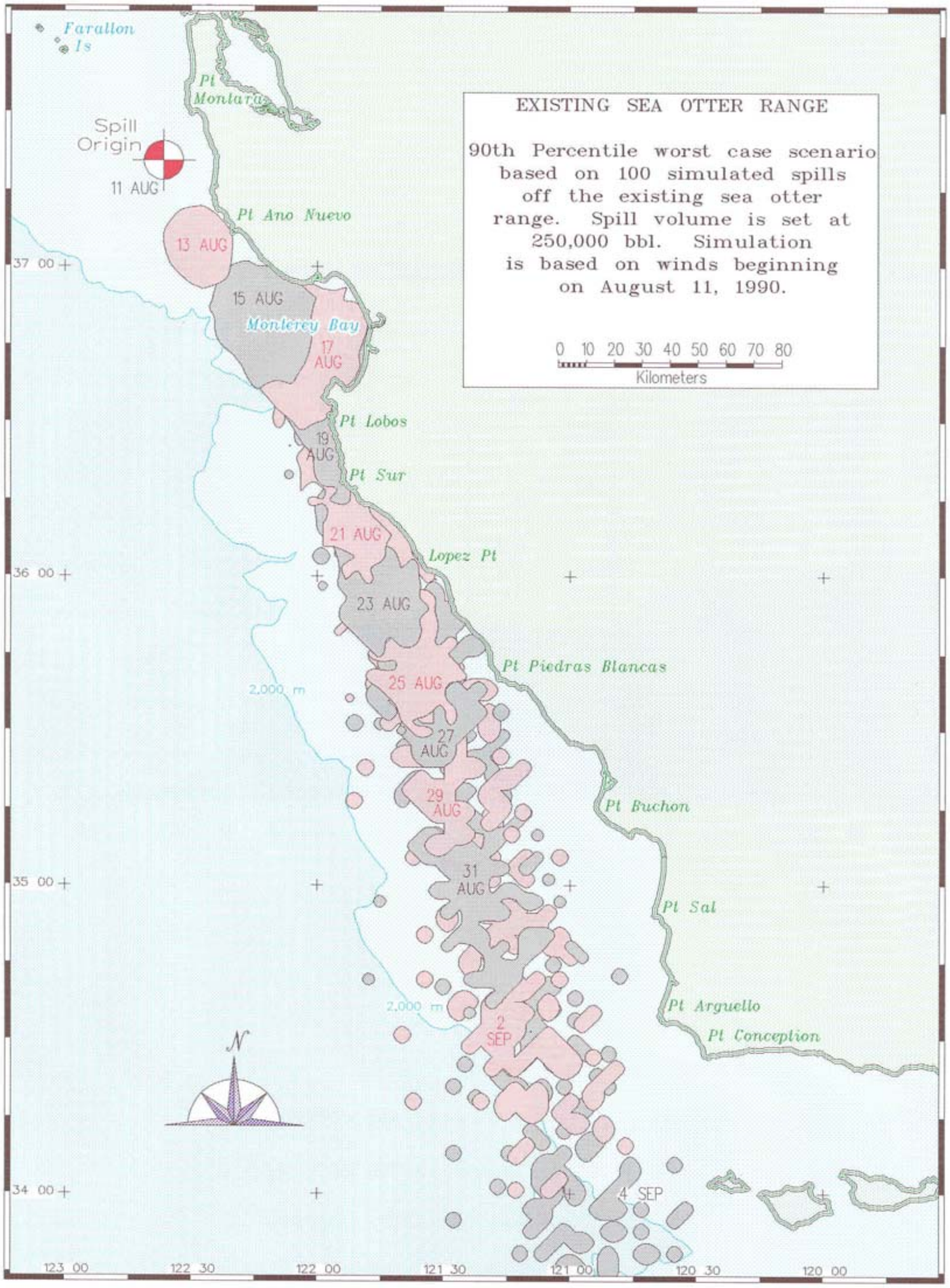

Figure 5. Trajectory of a simulated *Exxon Valdez*-size oil spill off the existing sea otter range. This simulation was the 90th ranking case out of 100 such spills launched within 25 nm of the coast. Alternating red and gray areas show the portion of the slick through time.

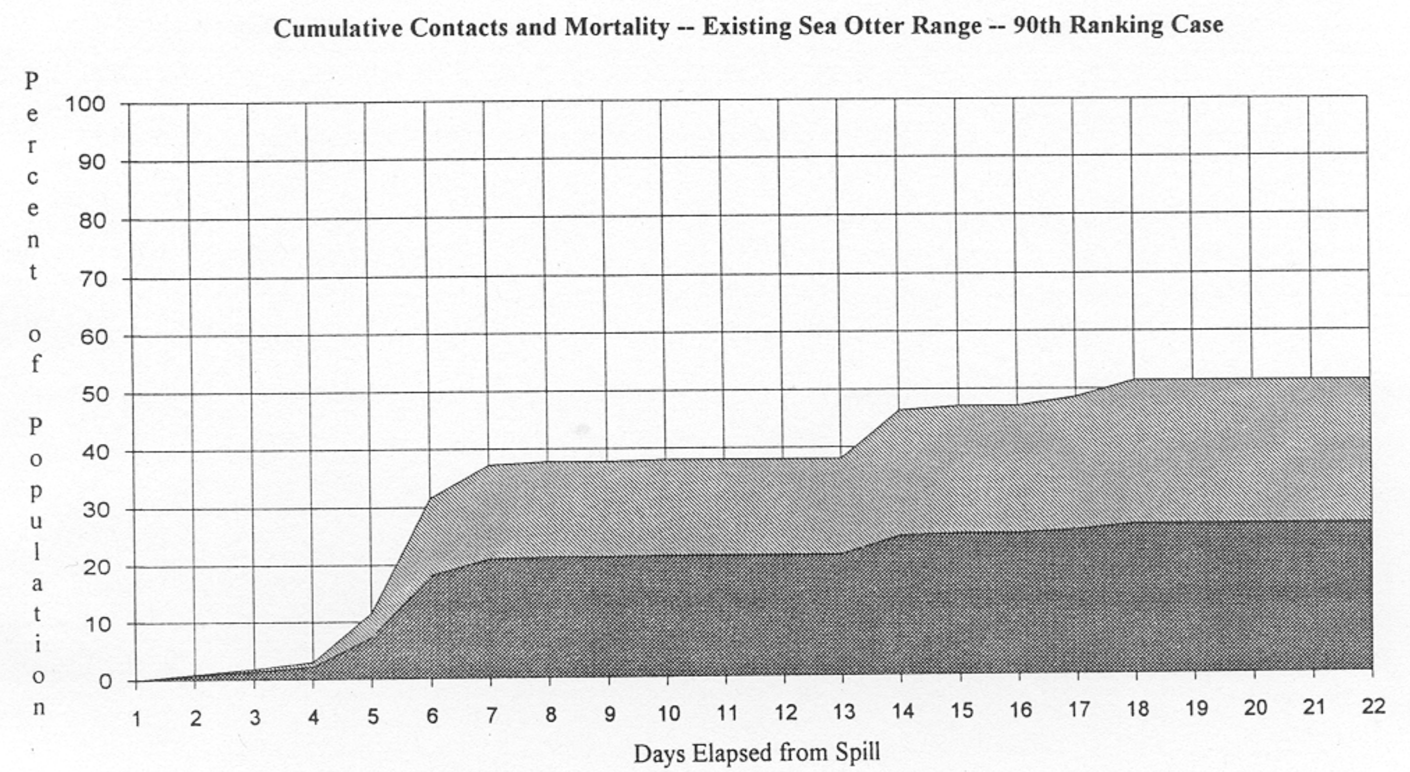

Figure 6. Cumulative percent of the total population in the existing sea otter range that would have been contacted or killed by an oil spill simulation. This simulation was the 90th ranking case out of 100 simulations of *Exxon Valdez*-size spills launched within 25 nm of the sea otter range. Light stippled area represents cumulative contacts, dark area represents estimated direct mortality.

Table 2. Existing Range: Number of southern sea otters contacted and estimated mortality resulting from 90th percentile reasonable worst case oil spill scenario.

Day	Number Contacted	Mortality[a]	Cumulative Contacted	Cumulative Mortality
0	0	0	0	0
1	17	13	17	13
2	15	11	32	24
3	20	14	52	38
4	146	87	198	125
5	344	186	542	311
6	96	49	638	360
7	9	4	647	364
8	0	0	647	364
9	6	3	653	367
10	0	0	653	367
11	0	0	653	367
12	0	0	653	367
13	141	56	794	423
14	12	6	806	429
15	0	0	806	429
16	27	10	833	439
17	48	17	881	456
18	0	0	881	456
19	0	0	881	456
20	0	0	881	456
21	0	0	881	456

[a] Mortality calculated using the relationship of sea otter survival and distance from the spill origin (Brody 1992); it is assumed that this number of sea otters will die, among those contacted, regardless of number of days of exposure. Calculations assume no mitigation of impacts by rescue and rehabilitation of sea otters.

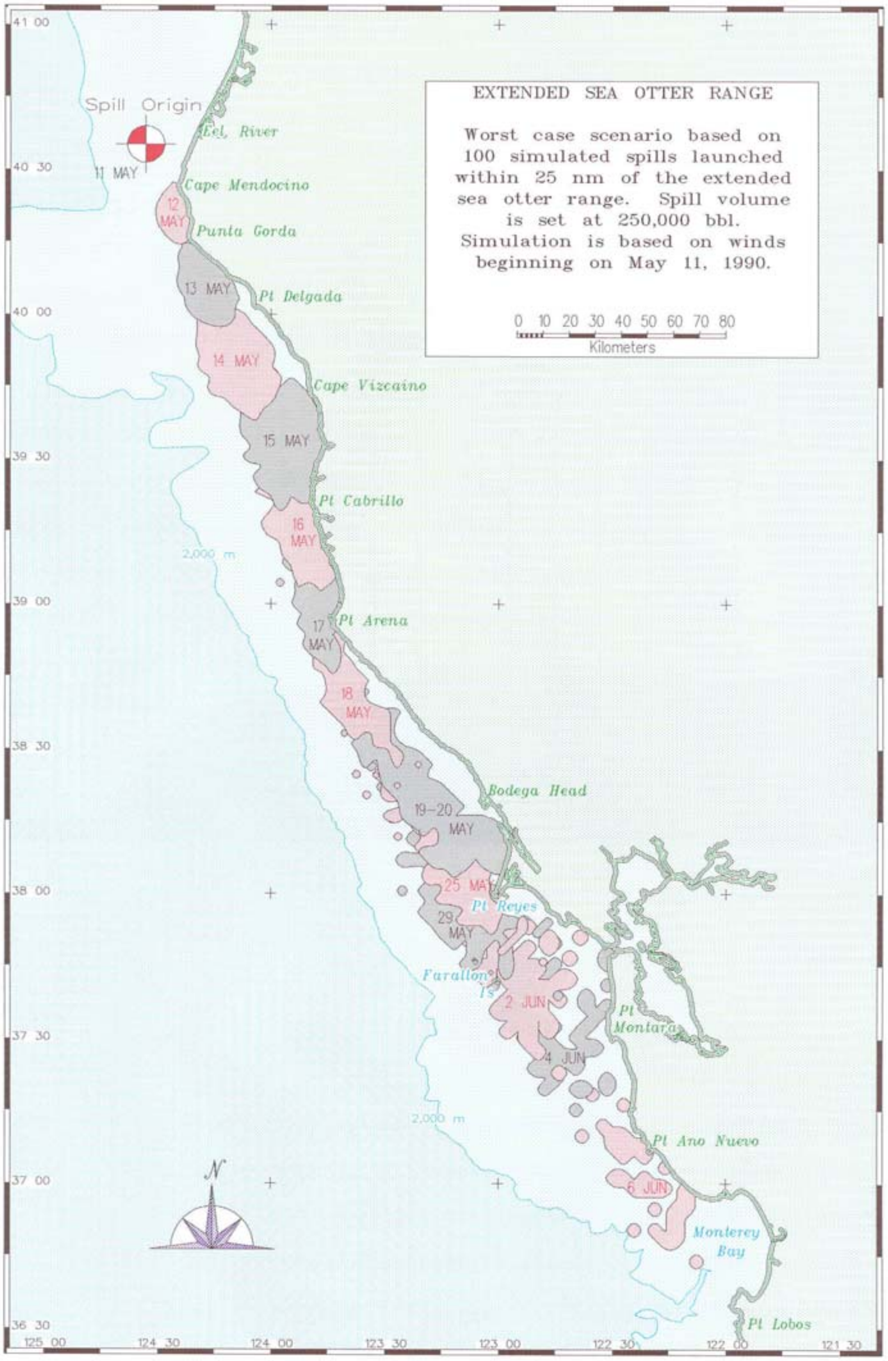

Figure 7 Trajectory of a simulated *Exxon Valdez*-size oil spill off the extended sea otter range. This simulation was the 100th ranking case out of 100 such spills launched within 25 nm of the coast. Alternating red and gray areas show the portion of the slick through time.

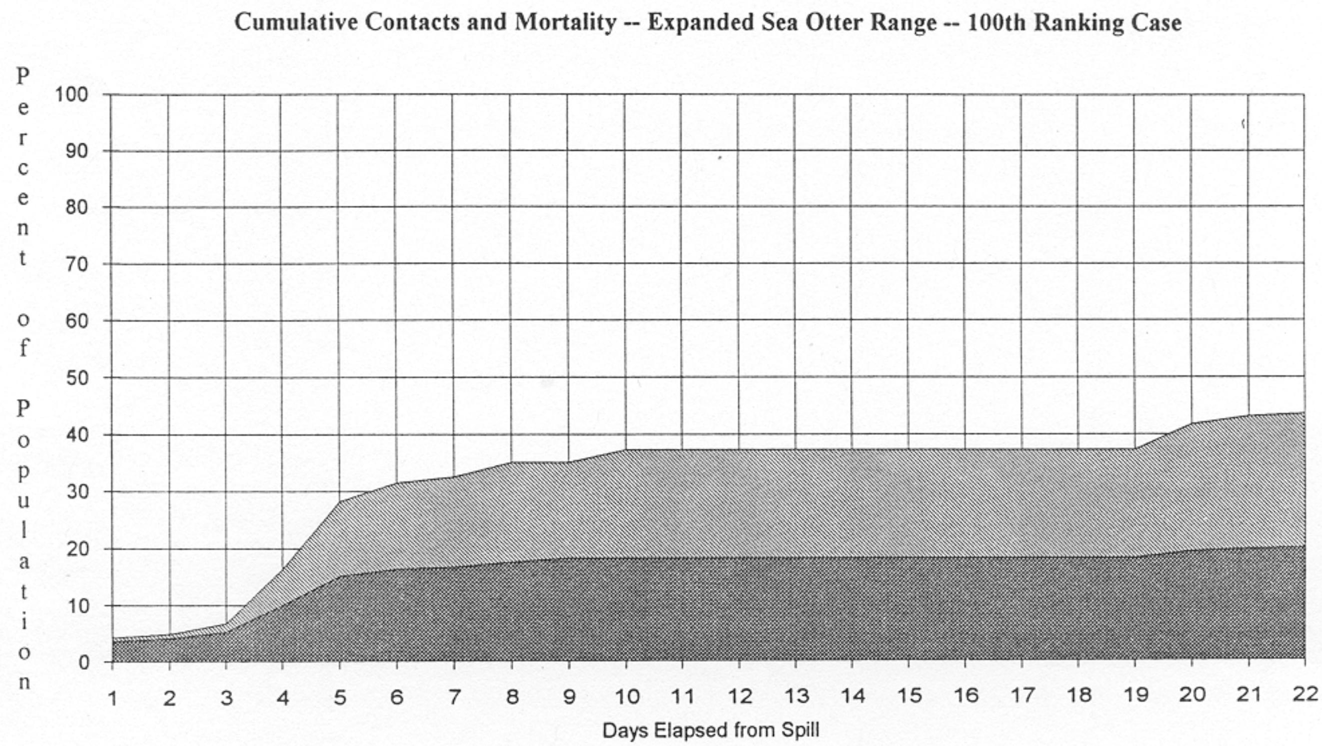

Figure 8. Cumulative percent of the total population in the extended sea otter range that would have been contacted or killed by an oil spill simulation. This simulation was the 100th ranking case out of 100 simulations of *Exxon Valdez*-size spills launched within 25 nm of the expanded sea otter range. Light stippled area represents cumulative contacts, dark area represents estimated direct mortality.

Table 3. Northern California Extended Range: Number of southern sea otters contacted and estimated mortality resulting from 100th percentile worst case oil spill scenario.

Day	Number Contacted	Mortality [a]	Cumulative Contacted	Cumulative Mortality
0	201	171	201	171
1	30	21	231	192
2	85	54	316	246
3	443	216	759	462
4	548	240	1307	702
5	151	57	1458	759
6	48	17	1506	776
7	120	41	1626	817
8	0	0	1626	817
9	101	31	1727	848
10	0	0	1727	848
11	0	0	1727	848
12	0	0	1727	848
13	0	0	1727	848
14	0	0	1727	848
15	0	0	1727	848
16	0	0	1727	848
17	0	0	1727	848
18	0	0	1727	848
19	204	55	1931	903
20	66	18	1997	921
21	21	6	2018	927

[a] Mortality calculated using the relationship of survival of a sea otter and distance from the spill origin (Brody 1992); it is assumed that this number of sea otters will die, among those contacted, regardless of number of days of exposure. Calculations assume no mitigation of impacts by rescue and rehabilitation of sea otters.

Distance From Shore

Simulated oil spills were released at each of six stations at increasing distances along five lines (Figure 9). The results of simulations for each station are shown in Figures 10a-10e and Figure 11. Offshore of Point Sal, Point Piedras Blancas, and Point Sur, the number of sea otters likely to be contacted by a spill decreases with increasing distance from shore. This occurs because spills that originate farther offshore are more likely to remain offshore, moving south-eastward with the prevailing winds into the Santa Barbara Channel. Spills occurring at the far southern end of the range off Point Sal, even those occurring close to shore, are unlikely to contact many sea otters because prevailing winds would move the slick steadily toward the southeast and because the density of sea otters is relatively low at the southern margin of the range. Spills offshore of Point Piedras Blancas occasionally result in significant numbers of contacts, especially spills originating within about 20 nmi of shore. Spills offshore of Point Sur show a pattern similar to those off Point Piedras Blancas, but with higher numbers of contacts at each distance offshore.

The number of sea otters likely to be contacted by a spill increases toward the northern end of the existing range. Spills originating in the area off Point Año Nuevo represent the greatest threat in terms of the number of sea otters that would be contacted. Spills originating in this area would typically move southeast, contacting the shoreline in the most densely occupied portions of the existing range. The relationship between the number of sea otters likely to be contacted by a spill and the distance offshore where the spill originates becomes more complex north of Point Año Nuevo. Spills originating farther seaward along the line extending west from San Francisco are actually more likely to contact large numbers of sea otters than are spills originating closer inshore. This occurs because oil from inshore spills is more likely to beach before reaching areas of high sea otter density. In contrast, spills originating further offshore drift a longer period of time before making landfall and are carried farther to the south. While older spills may undergo some weathering and decrease in toxicity, they will also have spread over a larger area and can be expected to contact a larger portion of the sea otter range.

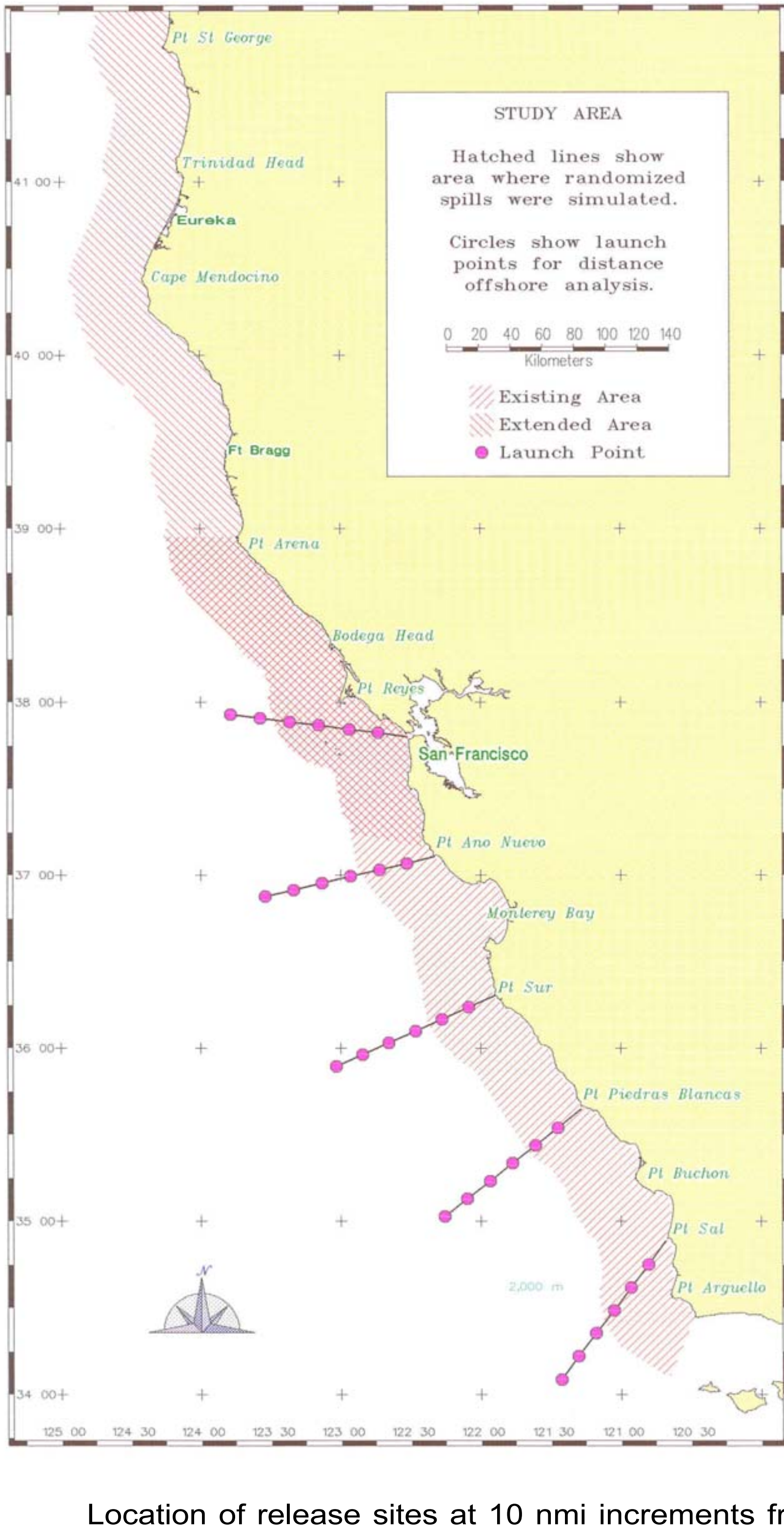

Figure 9. Location of release sites at 10 nmi increments from shore off the existing sea otter range.

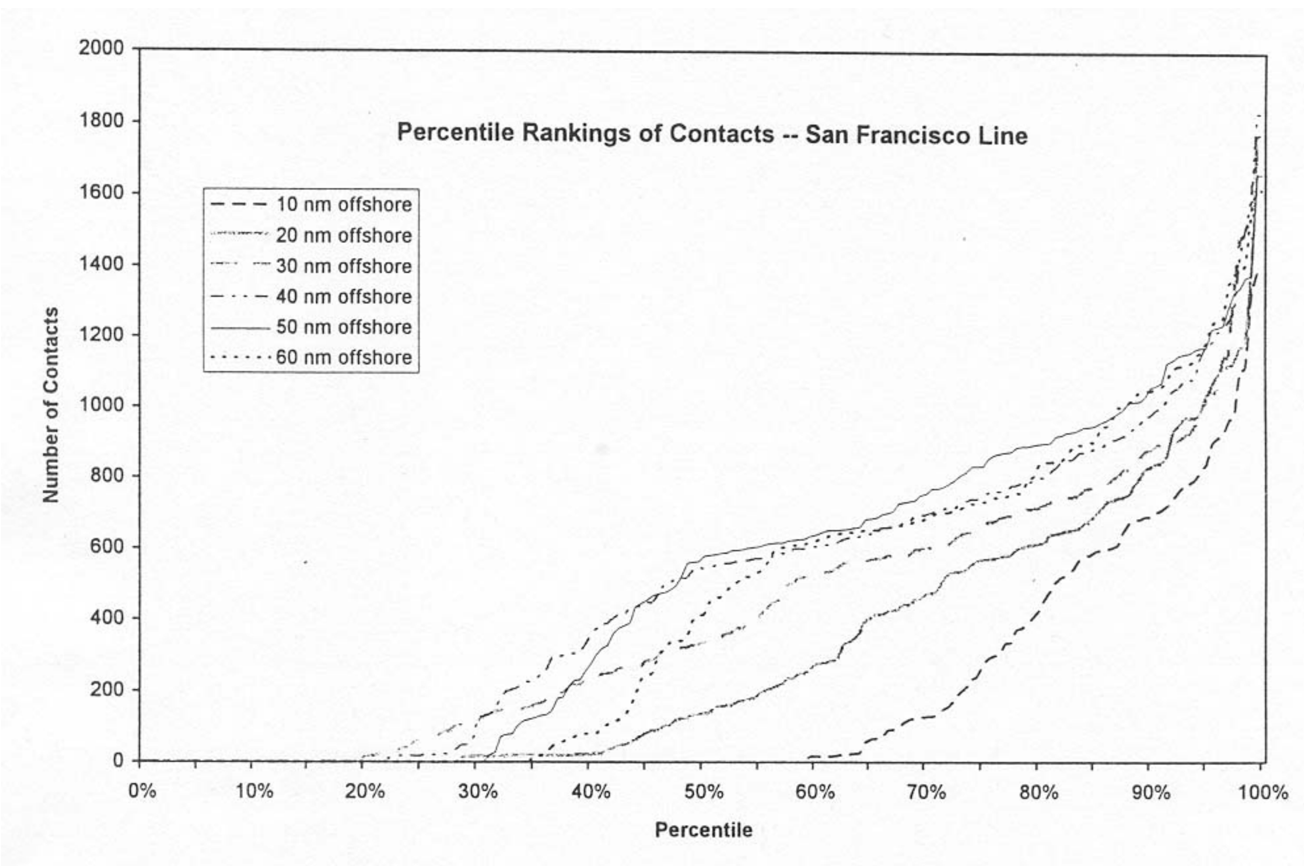

Figure 10a. Percentile ranking of number of sea otter contacts from spills at increasing distance from shore along San Francisco line.

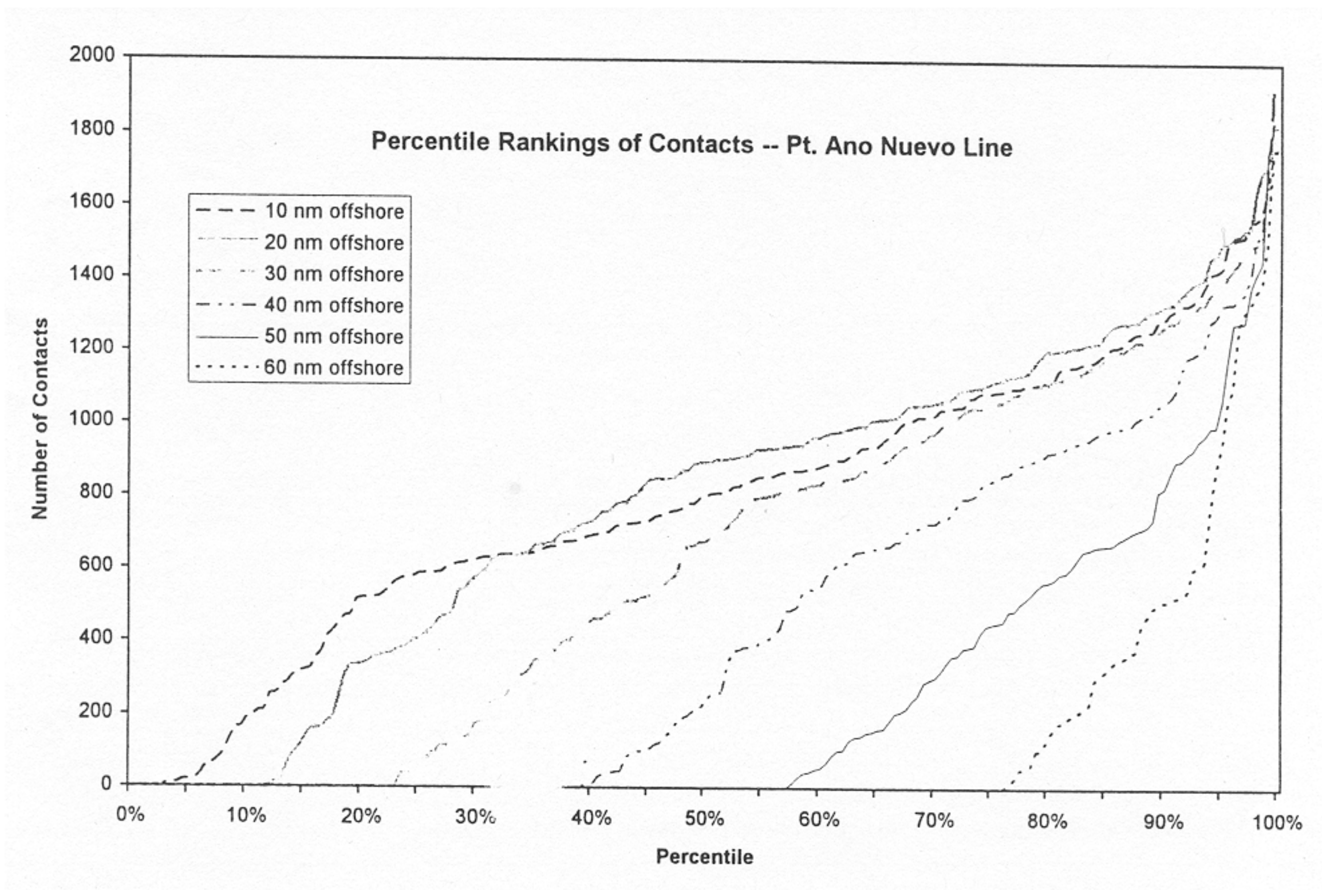

Figure 10b. Percentile ranking of number of sea otter contacts from spills at increasing distance from shore along Point Año Nuevo line.

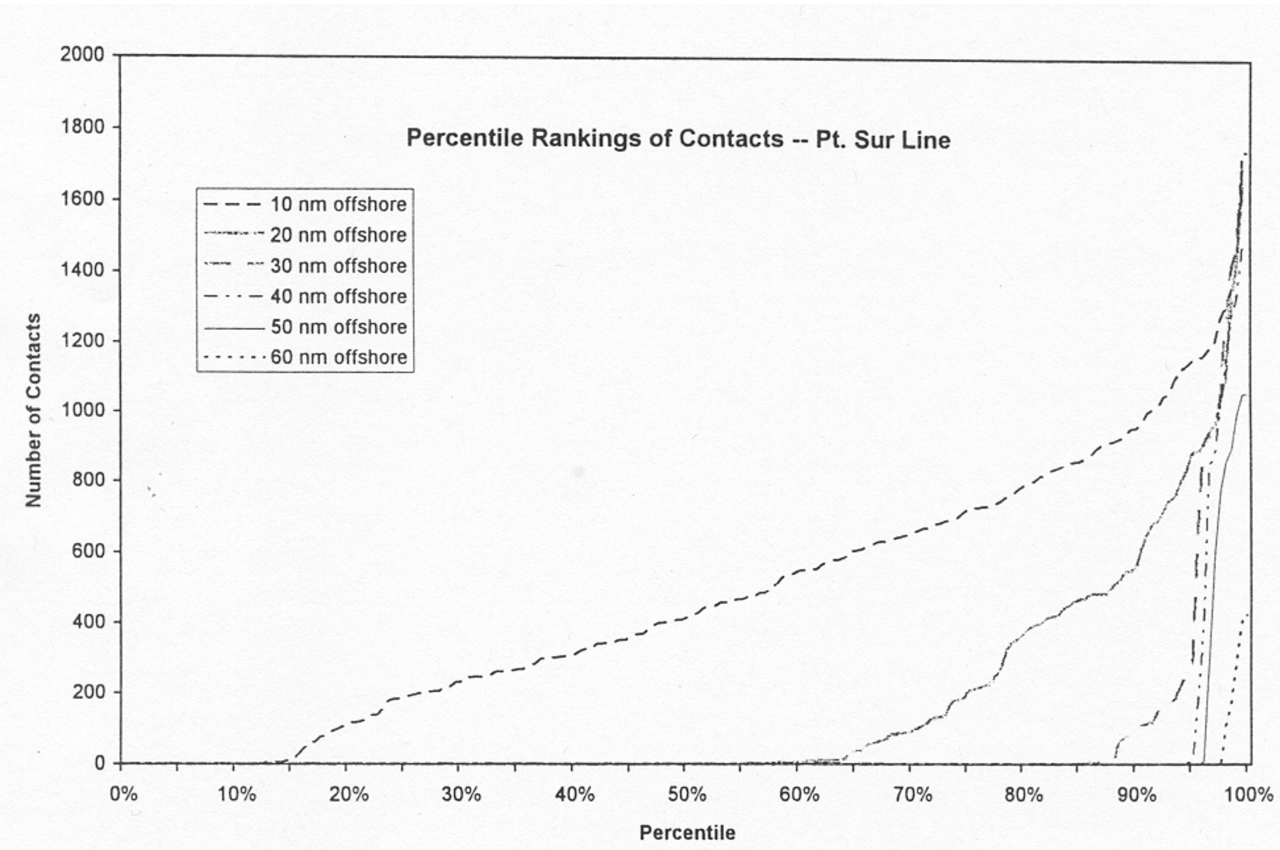

Figure 10c. Percentile ranking of number of sea otter contacts from spills at increasing distance from shore along Point Sur line.

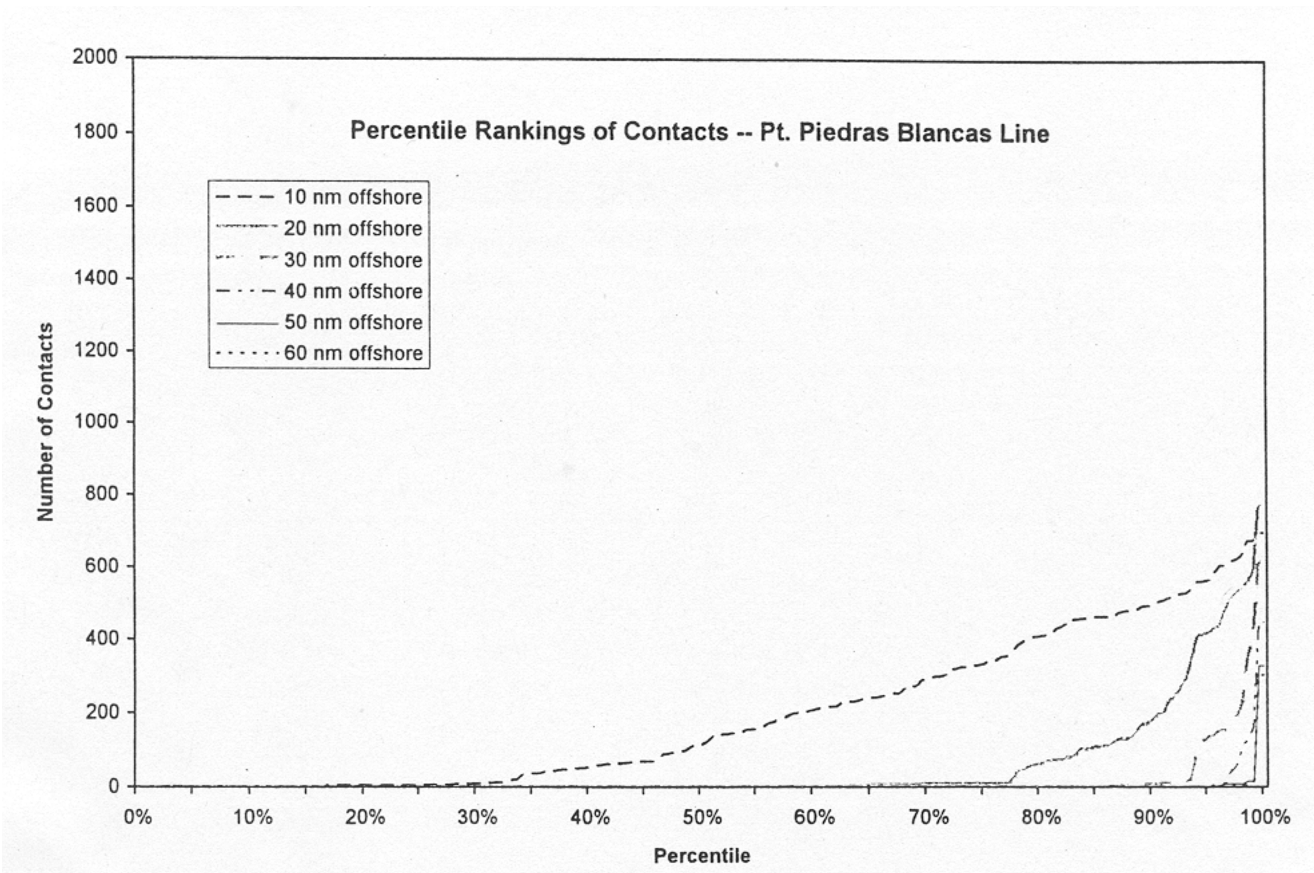

Figure 10d. Percentile ranking of number of sea otter contacts from spills at increasing distance from shore along Point Piedras Blancas line.

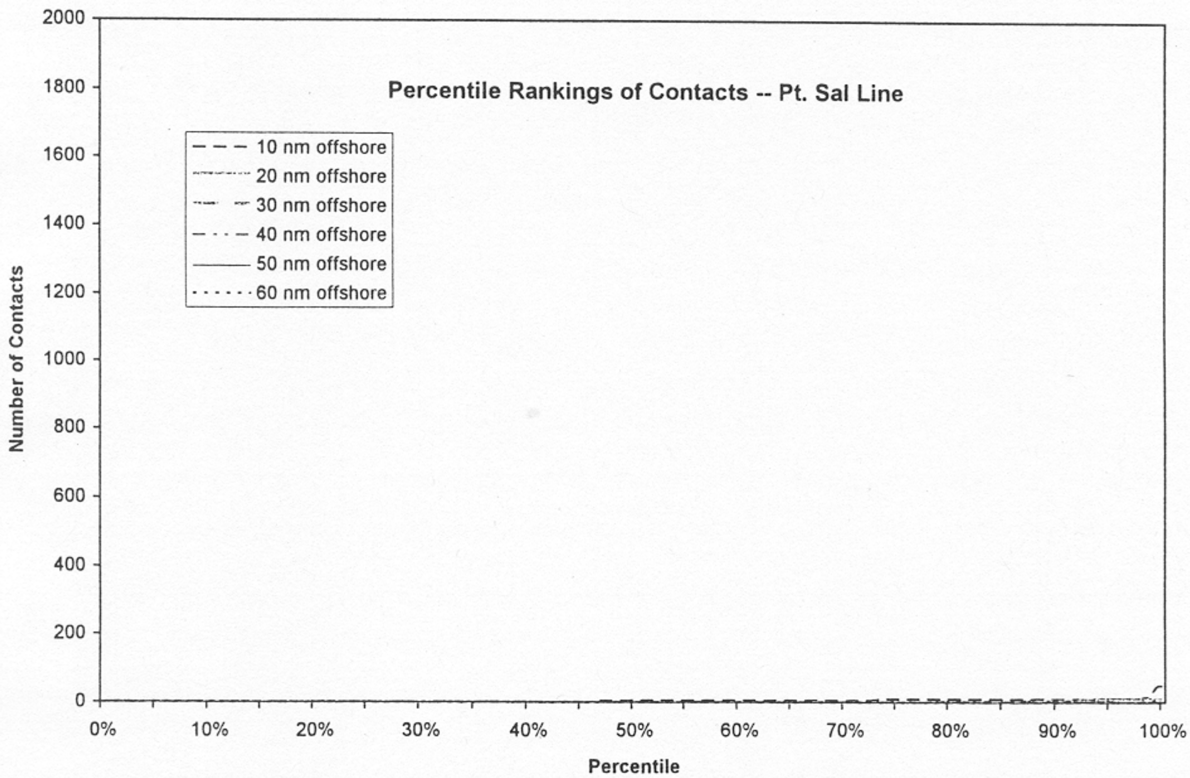

Figure 10e. Percentile ranking of number of sea otter contacts from spills at increasing distance from shore along Point Sal line.

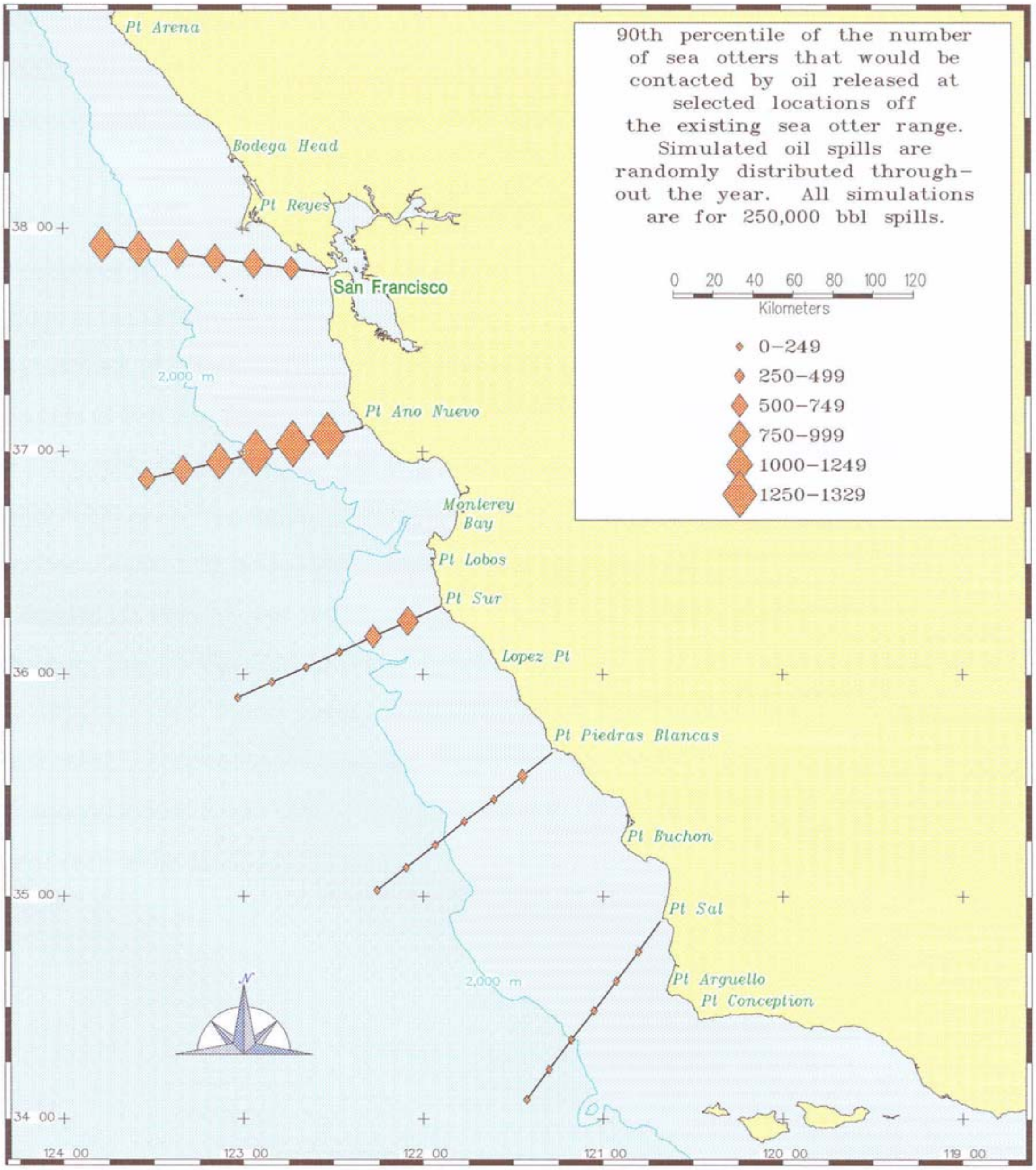

Figure 11. Sea otter contacts by release sites at increasing distance from shore for 90th percentile spill.

Analysis of simulated spills offshore of Point Año Nuevo shows some of the same pattern evident along the San Francisco line: spills originating 20 nmi offshore typically would contact more sea otters than those originating 10 nmi offshore.

The relationship between the number of sea otters contacted in model oil spill simulations as a function of distance offshore and north/south position where the spill occurred is summarized in Figures 11 and 12. Both figures show the 90th percentile of the number of otters contacted by simulated spills released at each of the six stations on each of the five lines. Clearly, the greatest risk to sea otters results from spills at the northern end of the range. Off Point Año Nuevo, the number of sea otter contacts remains high even for spills at distances of 50-60 nmi offshore. Off San Francisco, the number of contacts actually increases with increasing distance from shore. Consequently, efforts to reduce the likelihood of oil spills within 50 miles of land in waters from Monterey Bay to the Gulf of the Farallones may have little effect on reducing the risk to sea otters. For these spills, amelioration of the impacts may result from natural weathering and use of dispersants. For the range south of about Point Sur, a significant reduction in risk to sea otters may be achieved by reducing the likelihood of spills within 30-40 nmi of land.

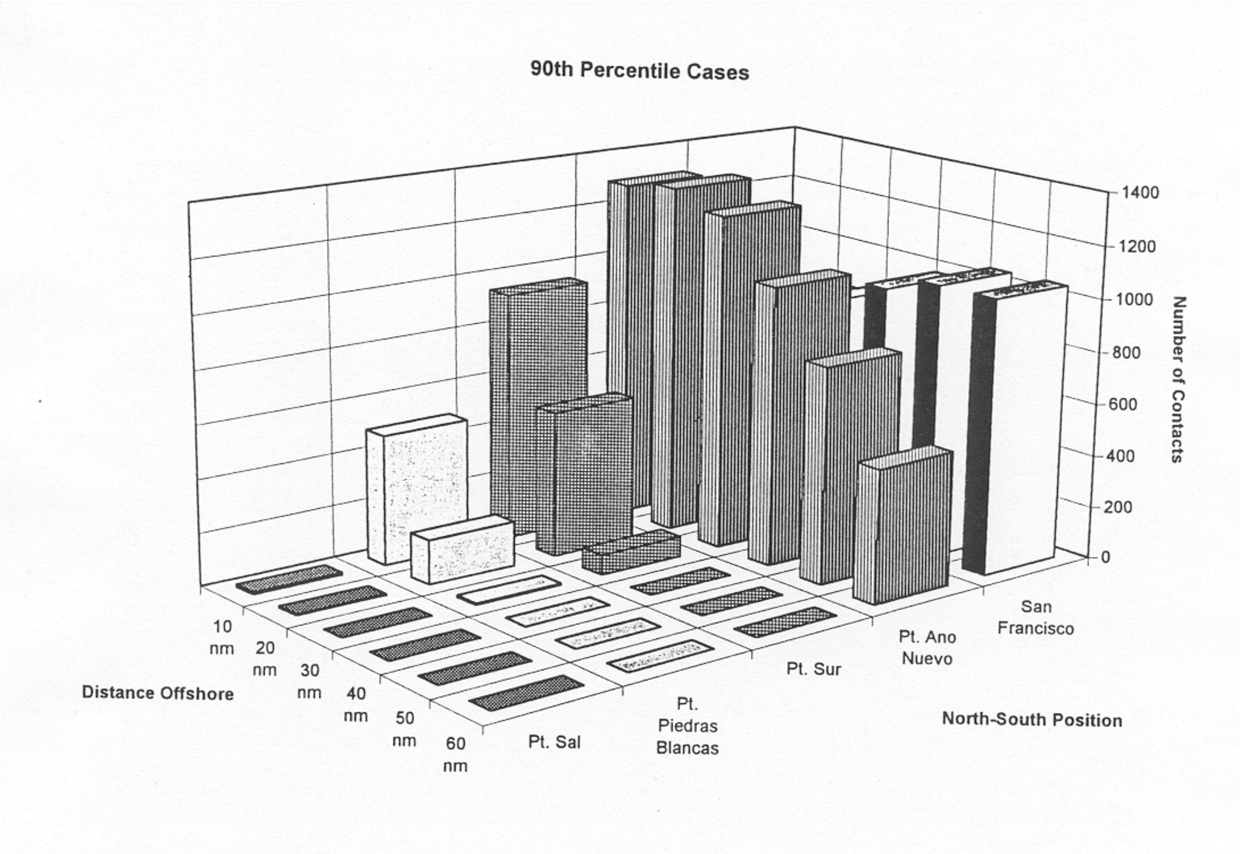

Figure 12. Sea otter contacts by distance from shore and latitude for 90th percentile spill.

Spill Size

To examine the effect of spill size on number of sea otters contacted, 200 simulated oil spills were released from randomly selected sites for each of the following volumes: 31,250 bbl, 62,500 bbl, 125,000 bbl, 500,000 bbl, and 1,000,000 bbl (Figure 13). Not surprisingly, the number of contacts at any percentile level is greater with increasing spill size, as is the likelihood that any otters at all will be contacted. However, the relationship of sea otter contacts and spill size is nonlinear. At the 90th or 95th percentile worst case level, roughly two to three times as many otters would be contacted by a 1,000,000 bbl spill as by a 31,250 bbl spill, despite a 32-fold increase in spill volume. Similarly, a 31,250 bbl spill results in a probability of no sea otter contacts of about 60.5%, while a 1,000,000 bbl spill results in a 12.5% chance of no sea otter contacts. Although relatively small spills tend to result in fewer sea otter contacts than do large spills, smaller spills do have the potential to contact many sea otters. For a 31,250 bbl spill, the 90^{th} and 95th percentile of sea otter contacts is 456 and 552 sea otters respectively, representing a substantial proportion of the total population in the existing sea otter range. The worst case scenario (i.e., the spill resulting in the greatest number of contacts among 200 simulations) resulted in 1,119 otter contacts, representing nearly one-half of the existing population.

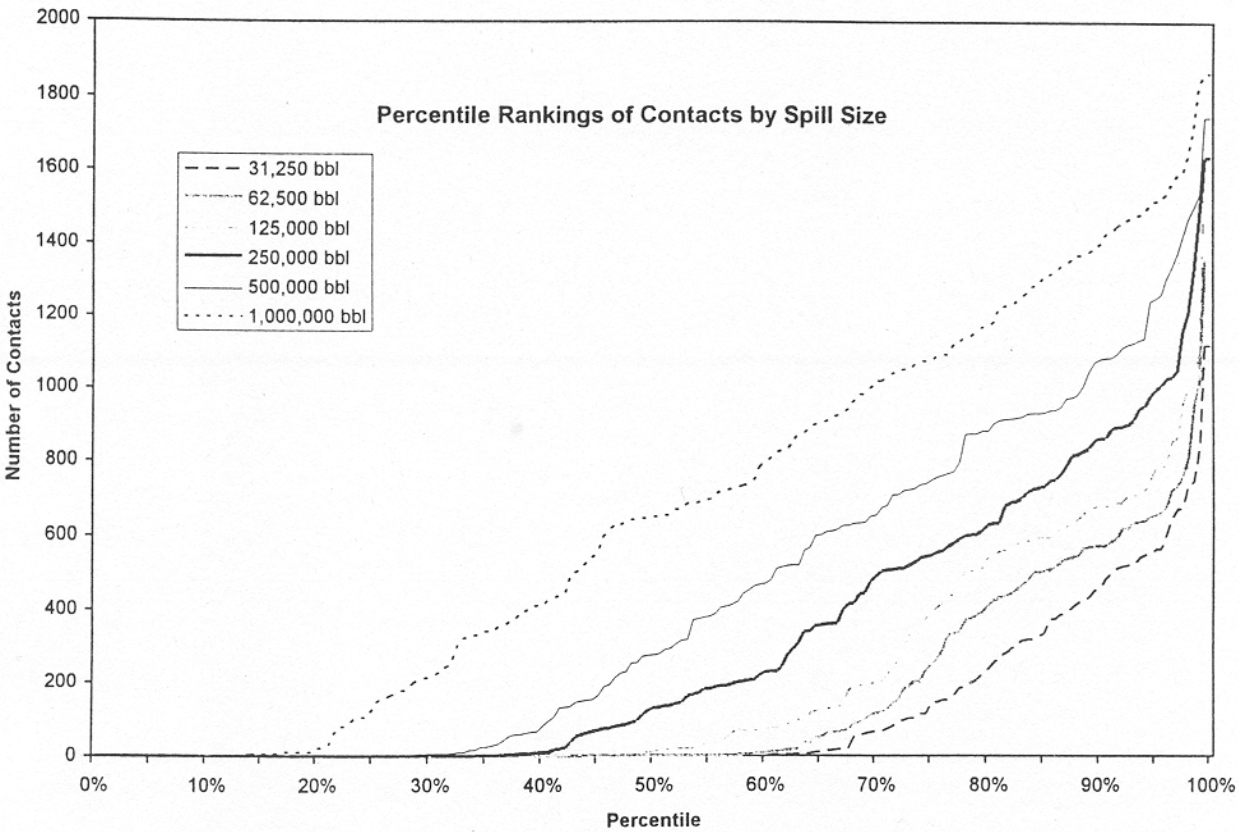

Figure 13. Percentile ranking of sea otter contacts by spill size.

Final Probabilities

The expected number of oil spills along the four tanker routes along the central and northern California coast was projected for a 30-year period (Table 4). In determining the occurrence rate, Anderson and LaBelle (1990) used a world-wide data base of crude oil spills from tankships that does not include spills from product carriers or barges and is not limited to spills in U. S. waters. However, there is no clear evidence that spills in U. S. waters are less frequent than elsewhere, nor do we have reason to suppose that the occurrence rate for spills from product carriers and barges would be substantially less than that of tankships carrying crude oil. The volume for each route included both crude oil and oil products, and transport by both tanker and barge. (Transport by barge accounted for less than 1% of all crude oil and about 8% of oil products.)

Table 4. Volumes of oil transported by tanker along the California coast and expected number of oil spills.

Route	1992 Volume (bbl)	30-yr Volume (billion bbl)	Expected Number of Spills
North Coast	38,662,107	1.160	0.161 [a]
Alaska/Overseas	219,196,895	6.576	2.959 [b]
South Coast	114,735,358	3.442	3.098
Estero Bay	3,560,489	0.107	0.096

[a]30-yr volume multiplied by 0.9 x 0.154

[b]30-yr volume multiplied by 0.9 x 0.5

The number of sea otters that may be contacted by oil spills along these routes was estimated from the trajectory model runs described above. We assumed that spills from North Coast traffic would occur with equal likelihood within 25 nmi from land along the coast between the latitudes of Point Arena and Point Año Nuevo. Spills north of Pt.

Arena were assumed to produce no impacts to the present population of southern sea otters. Spills from Alaska and Overseas tanker traffic arriving along the east-west traffic lane of the San Francisco TSS were assumed to occur within 25 nmi of land between the latitudes of Pt. Reyes and Point Año Nuevo. Spills resulting from South Coast traffic were assumed to occur within 25 nmi of land between the latitudes of Point Reyes and Point Conception. Spills south of Pt. Conception were assumed not to pose a threat to the present sea otter population. Spills originating from tanker traffic out of Estero Bay were assumed to occur within 25 nmi of the shore between the latitudes of Point Piedras Blancas and Point Conception.

The computation of final probabilities was based on the following additional assumptions:

> The occurrence of oil spills is an independent random event that can be modeled as a Poisson process. In other words, the occurrence of one oil spill in excess of 1,000 bbl does not affect the likelihood of subsequent spills.
>
> Spill size is independent of location and source and is assumed to be distributed according to data on spill events in U. S. waters from 1974-1985 (MMS 1986). We further assumed that a reasonable truncation of this frequency distribution was at 350,000 bbl, based on the size of tankers using San Francisco Bay and the South Coast Route.
>
> The sea otter distribution is static over the next 30 years, and remains unaltered from one spill incident to the next.

The upper bound of numbers of sea otters contacted by oil in the existing range during a 30-year period are provided at various levels of final probability in Table 5.

Table 5. Final probability levels and upper bound of numbers of sea otters in the existing range contacted by oil during a 30-year period.

Final Probability	Upper Bound of Sea Otters Contacted by Oil
10%	33
20%	118
30%	268
40%	455
50%	625
60%	785
70%	988
80%	1267
90%	1698
95%	2108
99%	2871

It should be emphasized that the number of otters contacted by oil would occur over a 30-year time frame, and may result from multiple spill events. Because it is assumed that the population acted upon is static and undiminished for each iteration of the model, it is probable that the analysis underestimates the impacts of multiple spills. This would be especially true if spills during the 30-year period occurred close together in time, not allowing for sufficient recovery of the population between spills.

In evaluating these estimates of number of contacts, the following points should be kept in mind:

> Spills are not equally likely to occur in all areas. The assumption that spills occur with uniform probability within a 25 nm band along the coast is an important simplification and should be evaluated. Some areas, such as the Gulf of the Farallones, may have a relatively higher risk of accidents due to the density of tanker traffic.
>
> The model samples from a frequency distribution of spill size with a cut-off at 350,000 bbl. This cut-off is provided so that the frequency distribution is truncated at the largest volume that might be released in a single accident affecting the sea otter population. It is possible that a very large crude oil tanker transiting between Alaska and Los Angeles/Long Beach could drift into waters within 25 nm of the coast; these tankers, with a capacity of 1,000,000 bbl, typically remain 50-100 nm offshore except on entry into the Santa Barbara Channel TSS. The model is sensitive to the frequency distribution of spill size and truncation volume; thus, these parameters should be further evaluated.
>
> Sea otter mortality cannot be derived in a simple manner from number of contacts. At the very least, the way an oil spill affects individual sea otters depends on the degree of exposure and properties of the oil. Thin or fragmented oil slicks, such as might result from smaller spills, may result in a lesser degree of

exposure. In the model, only very large spills were considered. However, the smaller of these may produce a lesser degree of exposure than the larger spills. The state of the oil contacting sea otters may also affect estimates of mortality. Fully weathered oil may be less toxic and less likely to adhere to a sea otter's pelage. The longer oil drifts, the more likely that weathering will occur. Therefore, spills farther offshore may have a lesser impact on the sea otter population than indicated by model results.

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APPENDIX C

USING INFORMATION ABOUT THE IMPACT OF THE
EXXON VALDEZ OIL SPILL ON SEA OTTERS IN SOUTH-CENTRAL ALASKA
TO ASSESS THE RISK OF OIL SPILLS
TO THE THREATENED SOUTHERN SEA OTTER POPULATION

by
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for
U.S. Fish and Wildlife Service
Southern Sea Otter Recovery Team
Ventura, California

1 September 1992

ABSTRACT

The work described herein uses information about the effects on sea otters of the Exxon Valdez oil spill in Prince William Sound, Alaska to enhance assessment of the risks of oil spills to the threatened southern sea otter population in California. Previous models of oil spills and otter populations are described briefly. Data on sea otters captured during rescue operations in Prince William sound are used to build a simple model of otter mortality as a function of distance from spill origin. The model allows assessment of the relative risk of an 11 million gallon spill occurring at different locations along the California coast, and identifies the tip of the Monterey Peninsula as the point of origin of a spill that would have the greatest effect on the population. Such a spill would expose 90% of the population to oil and result in a minimum range-wide mortality of 50%. The data is further analyzed in a life-table to arrive at estimates of the daily mortality rates of otters exposed to oil. These survival rates may be used to predict the mortality of otters exposed to oil at different times and for different lengths of time during an oil spill. It is hoped that these rates can be linked with explicit models of oil spill dynamics to construct mechanistic models of the potential impact of oil on the southern sea otter population. Limitations of the analyses are discussed, and direction for further research suggested.

Purpose.

The introduction to this report is brief. It is assumed that persons interested in this analysis are already familiar with the history of sea otter management in California and Alaska, and are familiar with the work of the various government agencies and universities involved in sea otter research, particularly those studies aimed at assessing the impact of the Exxon Valdez oil spill (EVOS) on the sea otter population of Prince William Sound and the Kenai Peninsula. The purpose of the present work is to use data about the impact of EVOS to improve understanding of the risk of oil spills to the southern sea otter population.

Previous work.

In the fifteen years since the Endangered Species Act provided the impetus for assessing the potential impacts of oil on the southern sea otter population, such assessments have revolved around three central questions: 1) what is the chance of oil contaminating the environment inhabited by sea otters?, 2) how does oil behave in the environment?, and 3) how do otters react to oil? Complete risk assessment must address all of these questions and link the answers in a realistic fashion. As it is impossible to study the effects of oil on a sea otter population experimentally, assessment of the risks of a spill to the southern population have been based on analysis of computer models constructed to simulate the dynamics of both oil spills and the sea otter population.

The principal model of oil spill dynamics is the OSRAM of USGS (Smith et al 1982), which models oil movement in detail but provides only a “yes or no” answer in regards to spills contacting specific geographic targets. Ford and Bonnell (1986) used this model to assess the risks of oil contacting sea otters in California. The majority of their analysis focused on predicting the probability of oil spills occurring and contaminating sea otter range; sea otter mortality in relationship to oil contamination was incorporated in only a general, delphic, fashion.

Bodkin and Udevitz (1991) linked a detailed oil spill movement model with known geographic distribution of sea otters along the Kenai Peninsula, and were able to estimate differences in potential exposure to otters during EVOS. Currently their model does not include specific relationships between exposure and mortality.

Brody (1988) developed a model of the dynamics of the California sea otter population that emphasized demographic detail but lacked any empirically-based incorporation of the effect of oil. The boundaries of any spill were static, and the probability of an individual otter dying within a spill zone was modeled as a function of 3 parameters describing the mortality associated with oiling, the ability of an animal to find local refuge within a spill zone, and the probability of an animal surviving a spill by leaving the spill zone entirely. While this seemed theoretically sound, there were no data with which to estimate these parameters; thus they were incorporated into the model as purely delphic parameters, where the user must speculate as to what the values of these parameters might be.

In reviewing previous work, it is obvious that, of the 3 questions mentioned earlier, the third one, “how do otters behave in oil?” is the one for which the answer is least developed. Data on behavior of individual otters inside a spill zone would obviously be very useful for estimating the effect of oil on a population. Though Bodkin and Weltz (1990) give anecdotal descriptions of the behavior of animals observed in oil during capture efforts, quantitative data was impossible to collect during the EVOS. The best estimates of potential oil spill mortality will come when we can relate oil exposure and sea otter mortality in a mechanistic fashion. Describing such a relationship, based on information from EVOS, is the focus of this report.

General approach.

To be able to model the effects of oil spills on a sea otter population in a mechanistic fashion, we would like to have a “dose-response" curve that gives sea otter survival as a function of oil exposure. Oil exposure might be measured by something like gallons of oil in the home range or decreased insulating ability of fur. There are ongoing efforts at elucidating what the relationship between exposure and mortality might be (Mulcahy and Ballachey 1991, Rebar 1991), but at present there is not enough data to describe the relationship in sufficient detail to include in a model. Until we can put oil exposure “on the x axis”, then, we must be satisfied with using parameters which we assume to parallel oil exposure as predictors of mortality. The most obvious of these parameters are time and distance from the spill origin. In general, as time elapses after the spill, oil weathers, aromatics evaporate, hydrocarbons degrade. With increasing distance from the spill origin, oil is diluted, stabilizes, and settles out of the habitat. Local weather events, currents, and mechanical properties of oil will, influence how well time and/or distance might reflect actual exposure of otters to oil after a given spill.

At this point we should consider how information from the Alaskan population might be applicable to otters in California. Perhaps the most obvious differences between Alaska and California that would pertain to an oil spill are in habitat physiognomy. The multitude of islands, arms, sheltered bays, and tide-influenced shallows of Prince William Sound are in sharp contrast to the open coast, high surf, and narrow zone of shallow water in central California. The geography of Prince William Sound provided refugia of oil-free habitat within the spill zone that would certainly be much rarer during a similar-sized spill in California. It is also likely that oil would move faster and probably weather faster in California. Thus the relationships between time, distance, and oil exposure after a spill will be different. It is unlikely, however, that there are any major differences in the mechanistic, physiologic relationship between individual animals' exposure to oil and mortality between the 2 populations. A given-sized spill will affect otters differently in Alaska than in California, but the difference is better thought of as a difference in the interaction of habitat and oil, not of otters and oil. This may seem a minor point, but it gives a conceptual framework around which we can apply information from Alaska to California. Again, the purpose here is not to build another model of oil spill dynamics, but to provide a more realistic link between such models and otter mortality, to concentrate on the third question raised in the introduction.

Data.

Since EVOS there has been monumental effort directed at quantifying the effect of the spill on the southcentral Alaskan sea otter population. Prior to the analysis described herein, a general survey of data that were and were not available was conducted by USFWS personnel (Table 1). Counts of local populations that would have allowed comparison of pre- and post-spill population sizes and direct calculation of spill-related mortality were not available. As mentioned earlier, information on the behavior of individual animals exposed to oil during EVOS would have been extremely useful, but, for various reasons, was not collected.

Maps of degree of oil-contamination of beaches were available, as were maps of locations of recovered carcasses. Attempts to correlate the degree of local contamination to number of carcasses recovered were stymied by an inability to relate number of local carcasses to local mortality rate (i.e., no information on pre-spill population size) and uncertainties about carcass movement and recovery rates. While there have been some estimates of carcass recovery rates (DeGange et al, in preparation, Wendell et al 1986), the applicability of these estimates to actual mortality rates is not well established.
In attempt to acutely mitigate the effects of EVOS, over 400 sea otters from Prince William Sound, Kodiak Island, and the Kenai Peninsula, were captured between March and August 1989. Much of the capture effort was directed at rescuing obviously stressed animals, but some of the effort was preemptive. Detailed records of the fate of captured animals were available, and, after considering the information above, it appeared that mortality rates of captured animals would provide the best insight into actual field mortality rates. The analysis in this report, then, focuses on the survival rates of these captured otters. This information was available in the N.R.D.A. relational data base (as it existed on 15 May 1992) maintained at the U.S.F.W.S. Research Center in Anchorage. Aspects of this data base that were relevant for the following analyses included the date and location of capture and the final disposition and date of disposition of each captured animal. Animals for which

any of this information was missing, or whose recorded location was not able to be located on a navigational chart, were excluded from analysis. A listing of the raw data extracted from the N.R.D.A. data base is appended.

The major assumption made about these data is that there is a direct relationship between the ability of an animal to survive after capture and the impact suffered from exposure to oil prior to capture; that those animals that died after capture or needed to be euthanized would have died from exposure to oil (though not necessarily on the day they were captured) and those that survived captivity would have survived in the wild. To be sure, there is much debate about this relationship, with some arguing that capture increased overall mortality (e.g. Ames 1990) and others believing in the efficacy of rehabilitation (e.g. VanBlaricom 1990). Perhaps in retrospect we can hope that any true rehabilitation was exactly balanced by the stresses of capture and captivity.

A second assumption is that animals did not change their general location during the course of the spill; that animals captured at a particular location had been resident there since the beginning of the spill. There is anecdotal evidence that capture operations, and the spill itself, did indeed cause some long range movements of animals, but there is no explicit information available on such movements. While such movements may have indeed influenced observed survival rates, it is not clear that they introduce a definite bias to lovsl survival rates.

<u>A simple model of oil spill mortality based on distance</u>.

Gait and Payton (1990) describe how the character of EVOS changed with time. With the idea that acute and sub-acute toxicity from oil will decrease with distance from the spill origin, the effect of distance from EVOS origin on survival was investigated. Most of the capture effort occurred in 7 general locations; fates of individual animals captured in each general location were tallied to give an average survival rate for that location. Results are plotted in Figure 1. It must be remembered that capture operations did not begin until 30 March 1989, 6 days after the Exxon Valdez ran aground, and at least 4 days after oil reached the islands of western Prince William Sound where capture operations started. Animals that died in the 4 days before capture operations began, when the oil was undoubtedly most toxic, were not available for capture and thus would not be included in the calculations of local survival rates. Overall mortality was almost certainly greater than the mortality of captured animals would indicate. For this reason, survival rates calculated from the fates of captured animals must be considered as maximums. A linear regression of these local survival rates on distance from the spill origin was significant (R^2=0.73, F=l7.5, p=0.009), but as the plot suggested a curvilinear relationship, log and reciprocal transforms were performed and tested. The best fit was the reciprocal transformation (R^2=0.97, F=192.0, p=0.0001), which yielded:

$$1/s = 0.88 + 137.97/d$$

where *s* and *d* are survival and distance from spill origin, respectively. This equation can be rearranged to give a "Michaelis - Menton" equation:

$$s = (1.13 \times d) / (156.6 + d)$$

which is illustrated in Figure 1. Equations of this form have been used to describe many relationships in biology (for instance population growth, enzyme kinetics, and response of predators to prey abundance...), and are attractive because the parameter estimates represent easily understandable quantities: the parameter in the numerator (1.13) represents the asymptotic value of the dependent variable (survival), and the parameter in the denominator (156.6) represents the value of the independent variable (distance) at which the dependent variable is at 1/2 of its maximum value. Note that this formulation forces the relationship between distance and mortality through the origin, that is, there is no survival, at the point of origin of the spill. This may in part compensate for the overestimate of survival that might result from measuring survival rates more than 4 days after the spill began.

Application of simple distance-based model to California.

We now have a simple relationship between distance from spill and otter mortality, and are in a position to see what the implications of the empirical relationship from Prince William Sound are for the southern sea otter population. To do this, we need an idea of how a similarly sized spill would affect the California coast. Ford (1985), studied the relationship between spill size, location, wind speed, wave height, water temperature and the length of coast affected by 39 near-shore oil spills. He found that the best predictor of the length of coastline impacted by a spill was given by:

$$\log(COAST) = -0.8357 + 0.4525 \log(VOL) + 0.0128(LAT)$$

where *COAST* = length of coastline affected in kilometers, *VOL* = volume of spill in barrels, and *LAT* = latitude of the spill origin in degrees; the standard deviation of the log of length of coast affected was 0.384. Given this relationship, an 11 million gallon (349,206 bbl) spill in Prince William Sound (latitude = 60 degrees) would be expected to impact 276 km of coast; +/- 1 standard deviation would bracket the estimate between 114 and 668 km. To determine the length of coast actually affected by EVOS invites discussion as to how exactly that might be measured, but all would agree that it was much more than the 275 km predicted by Ford's regression equation. Gait and Payton (1990) describe oil from EVOS being found on the shore at Chirokof Island, approximately 660 km from Bligh Reef. This is about 1 standard deviation above the expected length of coast affected, falling on the 84th percentile of expected length of coast affected.

According to Ford's (1985) relationship, a spill of 11 million gallons occurring off of central California (latitude = 37 degrees) would be expected to affect 140 km of coast. An 11 million gallon spill affecting a length of coast 1 standard deviation above the expected length would affect 334 km of coast, or about three quarters of the current range of the southern sea otter. The ninety-fifth percentile of the length of coast affected is 597 km, a distance longer than the current sea otter range.

Assuming that an oil spill will spread with the prevailing winds and current from north to south along the California coast, the numbers of otters that would be killed by a spill the size of the EVOS can be predicted by a simple deterministic simulation model that applies the relationship between distance and survival indicated in Figure 1 to the distribution of sea otters along the coast. In this model the spill moves down the coast from the point of origin and kills otters in the proportion predicted. For example, at 10 km from the point of origin, (1.135x10)/(156.6+10) = 6.8% of the animals at that location will survive the spill, while at 50 km from the point of origin (1.135x50)/(156.6+50) = 27.5% of the animals at that location will survive the spill.

In this model, the 5-fathom line ordinate system developed by USFWS and CDFG in their census activities is used to represent distance, and the most recent census data available (spring 1992, total count = 2101) is used to represent otter distribution. To determine the relative risks to the southern sea otter population of a spill the size of EVOS occurring at given points along the coast, spills affecting 334 km of coast were introduced successively every 5 km along the 5–fathom line, and the numbers of animals that would be killed by spills at each successive location totaled. Results are depicted in Figure 2, which may be interpreted as a graphic representation of the risk to the population as a function of the point of origin of an 11 million gallon spill.

The model predicts that the most damage would be done by a spill introduced near the tip of the Monterey Peninsula (5-fathom line ordinate 386), killing 1041 of the 2101 otters that were counted, or 49.5% of the population. The model was then run introducing spills affecting 140 and 597 kilometers of coast to reflect the probability distribution determined by Ford's (1985) analysis. These predictions are summarized in Table 2. Note that predicted mortality from spills affecting 343 and 597 kilometers of coast are the same. This is because the southern boundary of sea otter range in California is approximately 340 km south of the Monterey Peninsula, so oil spreading more than 340 km would kill very few additional otters.

The pattern of mortality predicted from a spill introduced near the tip of the Monterey Peninsula and affecting 334 km of coast is shown graphically in Figure 3. Note that this analysis implies that the spill originates on the 5-fathom line, and thus affects otters at distance 0 km from the origin. This would be possible if the spill resulted from a disabled tanker drifting into shallow water, but if the spill is presumed to result from an offshore source the distances used in the model would have to be adjusted accordingly.

A model of survival based on time of exposure.

The above distance-based model is independent of time. Time and distance from spill origin are intimately related, and in fact the processes that determine how far a spill will spread, such as wind and current, and how toxic or persistent a quantity of oil will be, such as dilution and evaporation, are all time-driven. The distance-based model was constructed first because distance was much easier to measure in retrospect, but to construct more useful mechanistic models of the relationship between oil spills and otters it will be necessary to model mortality as a function of time of exposure and age of the spill. Existing models of oil spill dynamics (e.g.the USGS OSRAM (Smith et al 1982)) iterate on a time basis, and integration of a model of sea otter mortality in relation to oil exposure into such a model will be facilitated if mortality is in some fashion driven by the age of oil.

Bodkjn and Weltz (1990) note that the ultimate survival of otters captured during and immediately after EVOS increased with elapsed time from the spill origin. Presumably this resulted in large part from a decrease in the toxicity of oil over time. If indeed this is the case we might think of each day of the spill being associated with a particular daily survival rate for otters exposed to oil on that day, and that the daily survival rate increases with time. The probability of an animal surviving a given time interval would then be given by the product of the daily rates, and the overall survival of animals will be a function of not only how old the spill is, but also how many days the animal is exposed to oil. For instance, an animal first exposed on the second day of the spill would have less chance of surviving the spill than one first exposed on the 10th day of the spill, and an animal exposed on days 10 through 12 would have a better chance of survival than one exposed on days 10 through 20.

To see if such a relationship is borne out in the data, it was assumed that captured animals were resident at their capture locations throughout the duration of the spill, and were first exposed to oil on the day that oil moved into the capture location. Using the description of oil movement in Gait and Payton (1990), the day that each captured animal was likely to have been first exposed to oil was determined on the basis of its capture location. Animals could then be grouped into “cohorts” of animals that were first exposed to oil on day *E* of the spill and exposed for *L* days, where *L* = *C* - *E* and *C* is the day the animal was captured. Note that this assumes that animals were exposed continuously from the time of first exposure until capture. Analysis of variance of the effect of length of time exposed *(L)* and day first exposed *(E)* on survival, weighted by the number of animals, conducted with the SAS General Linear Model procedure (SAS 1982) showed significant effects of both *E* and *L*:

Source	MSE	F	P<F
E	12.97	47.4	0.001
L	1.84	6.7	0.011
ExL	0.98	3.6	0.062

and subsequent regression gave significantly positive estimates for the effects of *E* and *L* (0.021 and 0.007, respectively, p<0.0001 for each), suggesting that observed survival actually increased with the length of time an animal was exposed to oil.

This result implies that animals captured later in the spill and after longer periods of exposure had already survived the worst effects of oiling -- many of the animals that were not to survive the spill had died prior to the commencement of capture operations, and were then not available for capture. That this was indeed the case was alluded to earlier, in the discussion of the distance-based model of survival. The fact that many animals may have died prior to being available for capture does not, however, affect calculations of daily mortality rates for the period of time during which capture operations were occurring, as long as the assumption that the effect of oil on an animal′s survival is not affected by capture holds. Thus a "life-table" type of analysis, where the population considered was the total number of animals captured during the spill, was conducted for 2 areas where sample sizes were large enough to do such an analysis. One area was the Eleanor Island - Green Island - Knight Island - Evans Island area of western Prince William Sound, which, according to Gait and Payton (1990), was first exposed to oil on days 4-6 of EVOS and from which the majority of captured animals were captured between about days 10 and 28 of the spill. The other was the western Kenai Peninsula, where animals were first exposed to oil on approximately days 18-20 of the spill and were captured between about days 40 and 110 of the spill.

Animals captured from these areas were subdivided by day of capture, grouping animals where necessary to provide sample sizes of at least 8 animals per group. None of these capture day groups encompassed more than a 5 day period of capture days for the western Prince William Sound animals or a 10 day period for the Kenai animals. Captured animals that could not be fit into a group were excluded from analysis, so that total sample sizes for western Price William Sound and the Kenai Peninsula were 105 and 109 animals respectively. The data thus organized is presented graphically in Figures 4 and 6. Tables 3 and 4 outline the calculations that this manipulation allows. Where there was more than 1 day between successive capture days the daily rate between capture dates was assumed to be constant and estimated by taking the nth root of the crude rate for the interval, where *n* = number of days between capture days (Heisey and Fuller 1985). As expected, the daily survival rates are greater for the Kenai Peninsula, as otters here were exposed to "older" oil.

Figure 5 plots the daily survival rates against the day after first exposure to oil for otters in western Prince William Sound. Daily survival rate increases with time, indicating again that mortality decreases with the age of oil. Regression lines of daily survival against time after first exposure are shown for linear regression and the Michaelis-Menton (reciprocal) regression. Again, the non-linear model provides a better fit on the basis of sum of squares, although the difference is not dramatic (R^2=0.43, F=6.419, p=0.0445 for the linear model vs. R^2=0.48, F=7.352, p=0.0350 for the non-linear model). Note that there is little difference between linear and non-linear models in predicted mortality over the range of times for which data was collected, but that the 2 models have drastically different implications for the mortality in the days immediately after a spill.

Figure 7 plots the daily survival rates against the day after first exposure on the Kenai Peninsula. While the plot does indicate an upwards trend, the regression is only marginally significant (R^2=0.27, F=13.33, p=0.07), indicating that the daily survival rate 20 days after the spill has leveled off. The mean and standard error of the calculated daily rates for the time period in Figure 7 is 0.9936 +/- 0.0086, which is not significantly lower than 1.0 (p=0.27). Either the daily survival rate is in fact still influenced by oil 20 days after the spill, but to a degree not detectable in our small sample, and/or the mortality observed at this point is in fact capture–related.

This uncertainty notwithstanding, having made the above calculations we can combine data from both areas to arrive at a general relationship between exposure of an animal to oil of a given age and mortality. To do this we translate the x–axis so that it represents the day after the spill started rather than the time after first exposure. For instance, the daily survival rate of 0.8764 calculated in the western Prince William Sound otters 4 days after exposure applies to oil 4+5 = 9 days old. Similarly, the daily survival rate of 0.9970 calculated for 25 days after exposure off the Kenai Peninsula applies to oil 25+20 = 45 days old. Combining data from the 2 areas, then, gives the plot in Figure 8. Finally, reciprocal and log-transformed regression analysis were performed on the combined data. Again, the reciprocal transformation fit slightly better (R^2=0.465, F=11.43, p=0.006) than the logarithmic transformation (R^2 = 0.416, F=9.58, p=0.010). The Michaelis-Menton representation of the reciprocal equation is:

$$s = (1.023 \times d) / (1.288 + d)$$

Standard errors of the parameter estimates are 1.023 +/- 0.014 and 1.288 +/- 0.267 (Figure 9). Caution is necessary when using regression equations to extrapolate outside the range of original data, but the implications of the above relationship for sea otter mortality in the first few days of a spill cannot be ignored. Animals exposed on day 1 of a spill have only a 45% (95% confidence interval = 35% - 59%) chance of survival; animals exposed continuously from day 1 through day 3 have only a 20% (95% confidence interval = 11% - 38%) chance of survival.

Reliability of the models.

In examining information on survival of sea otters captured during EVOS we have constructed 2 models of sea otter mortality as a function of oil exposure. Formal validation of these models is impossible because of obvious constraints on experimentation and data collection. Speculating on what the effects of violations of the major assumptions used in building the models would be on model predictions can serve as a measure of how reliable the models might be.

The most important assumption in the models is that observed mortality of captured sea otters represents actual field mortality due to oil exposure. If capturing animals did in fact lead to significant rehabilitation, field survival estimates are biased high. It should be remembered, however, that the majority of capture effort early in the spill was directed at obviously stressed animals, and that there was undoubtedly a bias toward capturing animals that were more likely to die if left in the field. In a more general sense, effects of acute mitigation, i.e., oil clean-up, are not taken into account.

The fact that there was undoubtedly a large amount of mortality before mitigation efforts even began is discussed earlier in this report. While this tends to overestimate survival as a function of distance from spill origin, the life-table approach to estimating daily survival rates escapes this problem by estimating daily rates during the time that capture operations were occurring. Again, however, since early capture efforts were not at all random, the calculated daily rates might underestimate actual survival rates. The extrapolation of survival rates to the immediate post spill period (i.e., days before capture operations began) is obviously highly dependent on the form of model chosen. The “Michaelis–Menton” model is intuitively appealing and easy to apply, and the small sample sizes involved do not justify fitting models of more than 2 parameters, but it is undoubtedly an oversimplification that could potentially lead to large errors in estimates of the survival rates immediately after a spill. Furthermore, the analysis assumes that daily survival rates are independent of the number of days exposed. If, as might very well be the case, exposure on a previous day reduces an animal′s chance of survival if exposed on the next day, the probability of surviving continuous exposure during the first few days of a spill would be even smaller than the model predicts.

The second major assumption used in constructing the models is that animals did not change location during the spill. Since both models depend on survival calculated for specific areas, violations in this assumption affect the reliability of-the estimates. It is very likely that both the oil itself, and the associated human activity, including, obviously, capture operations, increased otter movements during the 4 month period considered in the analyses. If otters actively avoided oil and human activity successfully, survival estimates based strictly on the geographic proximity of otters and oil are biased high. This point becomes more important when the differences in habitat between California and Alaska are considered; the relative lack of local refugia and the linearity of the coast in California would make both chance and purposeful avoidance of oil more difficult there, and thus decrease local survival.

Finally, both models address only the acute and subacute effects of oil on sea otter population dynamics. Evidence of chronic effects of oil on the habitat is accumulating, and those effects might ultimately prove to be just as important as immediate mortality in regards to the long-term health and survival of sea otter populations exposed to oil.

Conclusion.

Despite the caveats outlined in the preceding discussion, the models presented herein can go far towards answering the question posed in the introduction, “how do otters react to oil?” An inability to formally validate the models does not render them useless as long as the resolution and purpose of the models are kept in mind. The very fact that recognizable patterns present themselves in the face of such uncertainty about the data collection is reassuring.

The distance-based model gives us an idea of the magnitude of the effect that a spill the size of EVOS might have on the southern sea otter population. The amount of coast affected by EVOS fell well within the range predicted by Ford′s (1985) simple model of oil spill dynamics, providing some support for the reliability of that model, and indicates that the entire range of the southern sea otter could very easily be affected by a spill the size of EVOS. A population-wide survival rate of 50% should be considered a best-case scenario should such a spill occur. The distance-based model also allows, for the first time, an empirically based analysis of the risk of a spill in relation to the location of origin.

The time-based model describes the chance of an otter surviving a day of exposure to oil of a given age. It can be used to calculate the expected survival of animals exposed to oil at different times and for different time intervals during a spill, and thus can be combined with explicit models of spill movement to arrive at more realistic predictions of mortality. The exact parameter estimates are only a starting point for making such predictions, and any linking of this model with spill dynamic models must include sensitivity analyses that explore the effect of liberal variation around these estimates. Perhaps more important than the parameter estimates themselves is the fact that a simple relationship between mortality and exposure precipitated. The Michaelis-Menton formulation is a theoretically sound, and now empirically supported, framework within which to further refine estimates of the effect of oil on sea otters.

Finally, these analyses indicate what future work will most increase our understanding of the relationship between otters and oil. On the theoretical side, it is time to link detailed models of oil spill dynamics with models of sea otter population dynamics. On the empirical side, we must be prepared with research objectives for the next oil spill in sea otter habitat, and these objectives must include making unbiased observations of otter behavior and mortality in oil.

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Table 1. Summary of available types of data about the impact of EVOS on the southcentral Alaskan sea otter population. Compiled by U.S.F.W.S. personnel in May 1992.

Available data.

1. Boat survey data (1984/85) of sea otter population in Prince William Sound.
2. Boat survey data (1989, post-spill) of Prince William Sound sea otter population.
3. Helicopter surveys (1989, post—spill) of Kenai Peninsula, Kodiak Island, and Alaska Peninsula populations.
4. HAZ-MAT model -- video of oil movement in 3 hour increments.
5. Map of beaches contaminated by oil in categories of heavy, medium, light, and no contact.
6. Number of otters captured by area and their fates.
7. Number of beached carcasses recovered, by area.
8. Bodkin and Udevitz′s INTERCEPT model.
9. Estimates of mortality rates of otters occupying 2 areas of known level of oil exposure.
10. Estimates of carcass recovery rates from California and Kodiak Island.

No data available.

1. Abundance of otters by specific area prior to exposure to oil.
2. Behavior of otters exposed to oil.
3. Movement of otters during period of exposure to oil.
4. Change in actual mortality rates of otters relative to age of oil (i.e., time since spillage) at time of contamination.
5. Percent of total mortality of oiled otters in the field represented by number of beached caráasses found.
6. Movement of otter carcasses from point of oil contamination or death to site of collection.

Figure 1. Crude survival rate as a function of distance from spill origin (at Bligh Reef) for 297 sea otters captured in rescue efforts during the Exxon Valdez oil spill. "Michaelis-Menton " regression line is plotted.

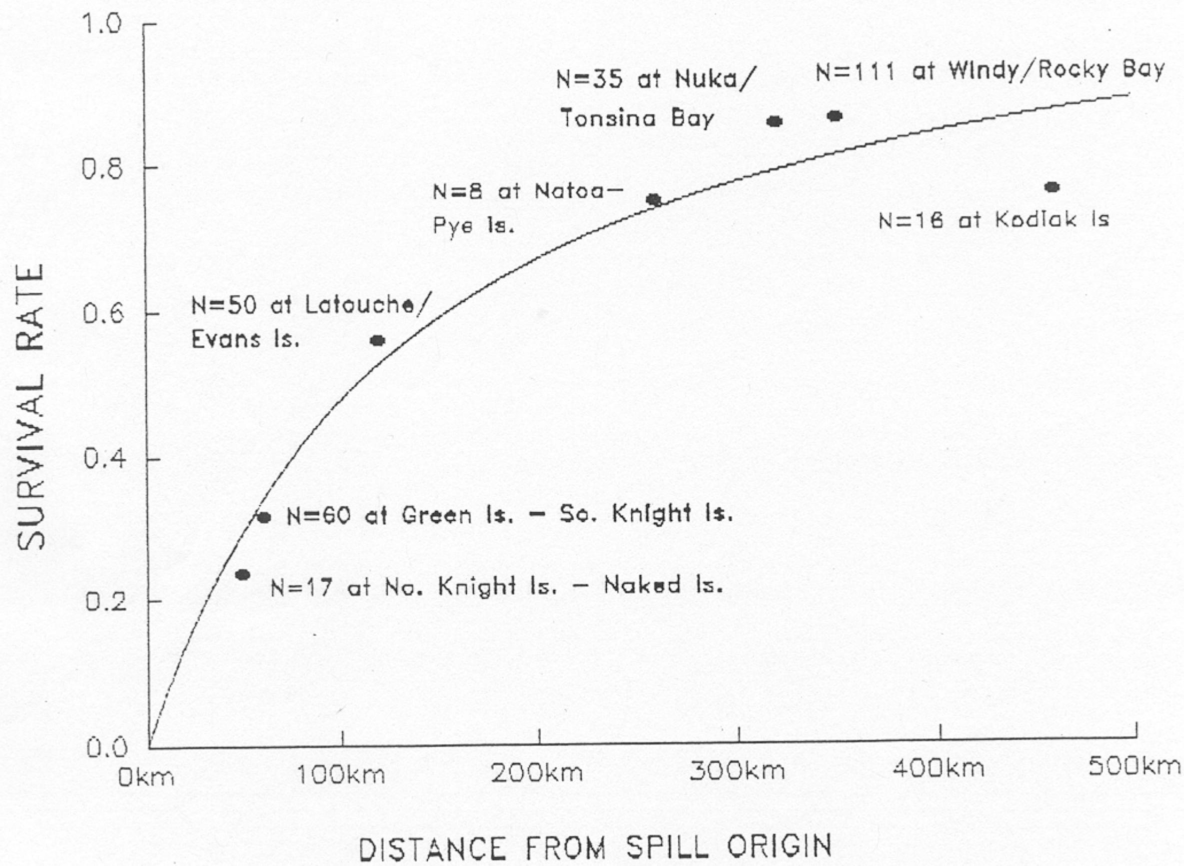


Figure 2. Relative risk of an 11 million gallon oil spill affecting 140 kilometers of coast as a function of location along the 5-fathom line. Y-axis is the predicted number of deaths, assuming a range-wide population of 2101 animals.

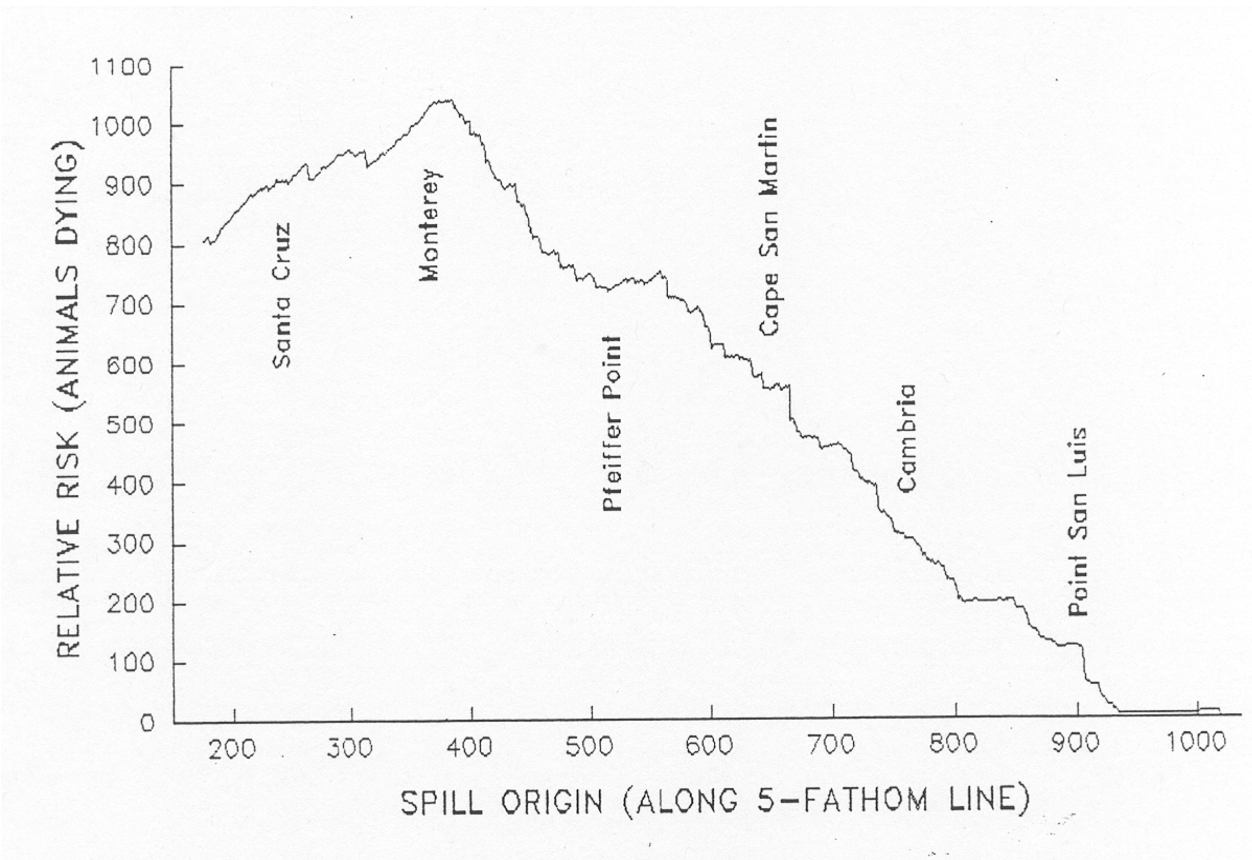


Table 2. Summary of predicted effect of an 11 million gallon oil spill occurring near the tip of the Monterey Peninsula, according to the simple model of mortality as a function of distance from spill origin. Based on Ford's (1985) relationship between spill volume and length of coast affected, the relationship between distance from spill origin and otter mortality observed in EVOS as described in text, and the Spring 1992 census of the southern sea otter population.

Length of coast affected by spill:	140km	334km	597km
Percentile of expected distribution of length affected:	50	84	95
Number of otters in spill zone:	1172	1883	1883
(Per cent of total population):	(56)	(90)	(90)
Number of otters killed:	778	1041	1041
(Per cent of total population):	(38)	(50)	(50)
Percent of otters in the spill zone that are killed:	66	55	55

Figure 3. Graphic representation of the distribution of sea otters along the California coast, and the proportion that would be killed by a 11 million gallon oil spill affecting 343 kilometers of coastline from Pt. Pinos south. Each bar represents the population in a 10 kilometer section of coast.

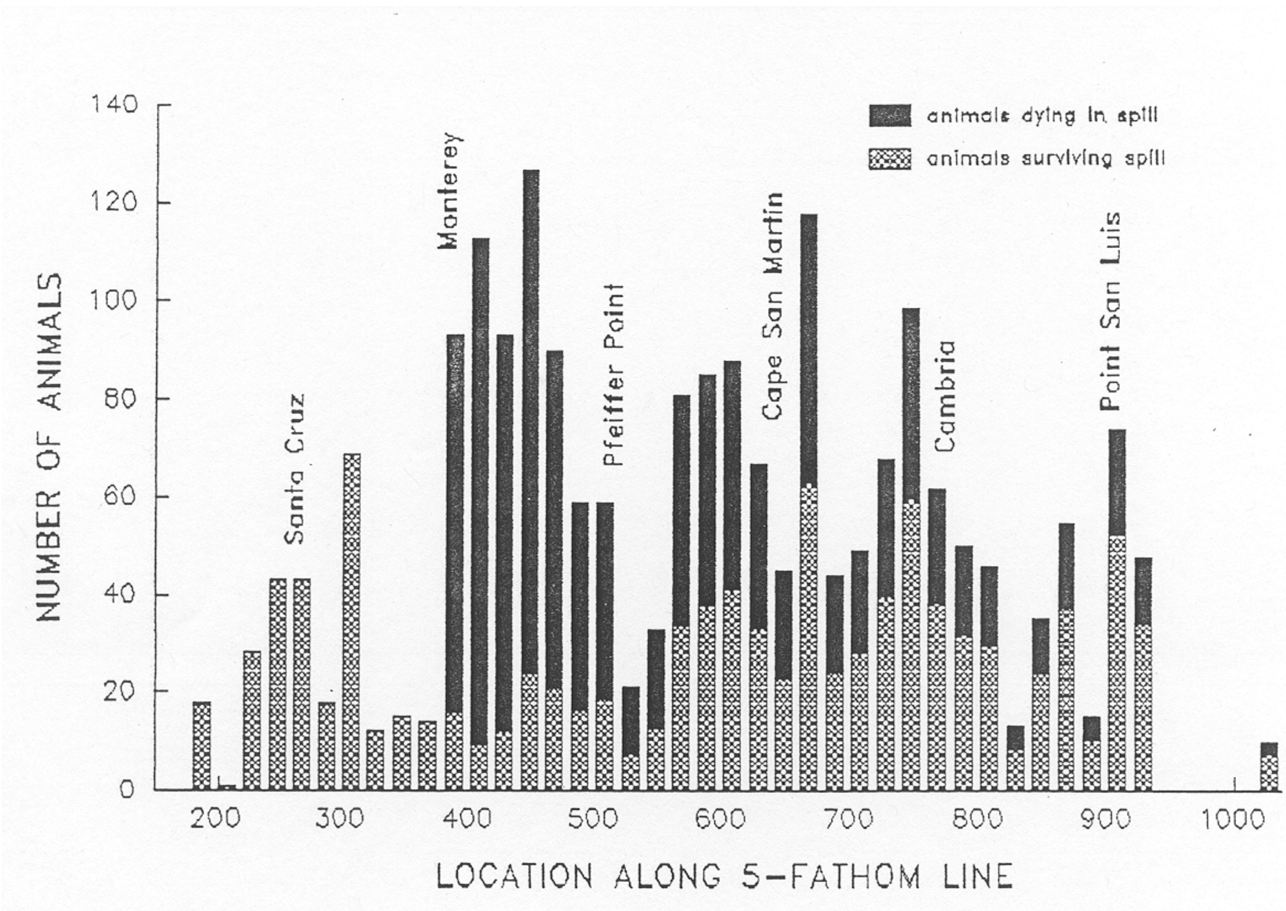


Figure 4. “Survivorship curve” for 105 sea otters first exposed to oil on approximately day 5 of EVOS in western Prince William Sound and subsequently captured.

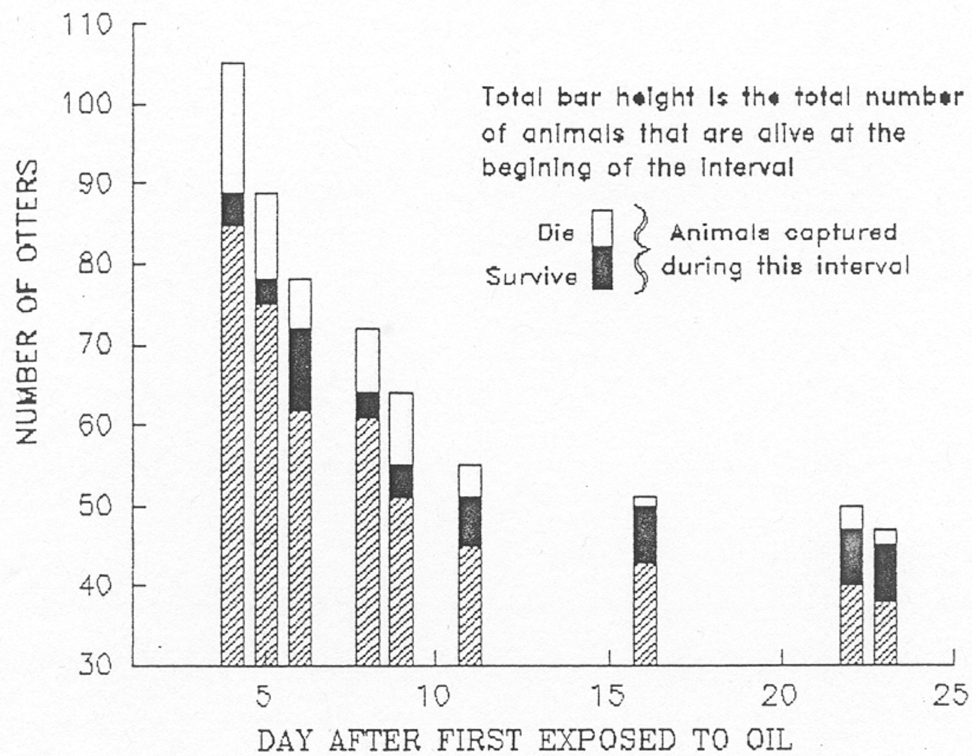


Table 3. Calculations used in estimating daily survival rates for 105 captured sea otters that were first exposed to oil on approximately day 5 of EVOS in western Prince William Sound.

x	N_x	N_{x+1}	i	d_x (c_x)	$s_{i,x}$	s_x	X
4	105	89	1	16 (20)	.8476	.8476	4
5	89	78	1	11 (14)	.8764	.8764	5
6	78	72	1	6 (10)	.9231	.9231	6
8	72	64	2	8 (11)	.8889	.9428	7
9	64	55	1	9 (13)	.8594	.8594	9
11	55	51	2	4 (10)	.9273	.9630	10
16	51	50	5	1 (8)	.9804	.9951	13
22	50	47	6	3 (10)	.9400	.9900	19
23	47	45	1	2 (9)	.9575	.9785	23

COLUMN DEFINITIONS:

x Number of days exposed to oil.
N_x Number of animals alive on day x.
N_{x+1} Number of animals alive on day x+l.
i Number of days in interval between successive capture dates.
c_x Number of animals captured on day x.
d_x Number of animals captured on day x that will die.
$s_{i,x}$ Survival rate for interval i, beginning on day x.
s_x Daily survival rate in interval i ($s_i^{1/i}$).
X Day at which s_x applies (midpoint of interval i).

Figure 5. Calculated daily survival rates for 105 sea otters first exposed to oil on approximately day 5 of EVOS in western Prince William Sound and subsequently captured. See text for explanation of regression lines.

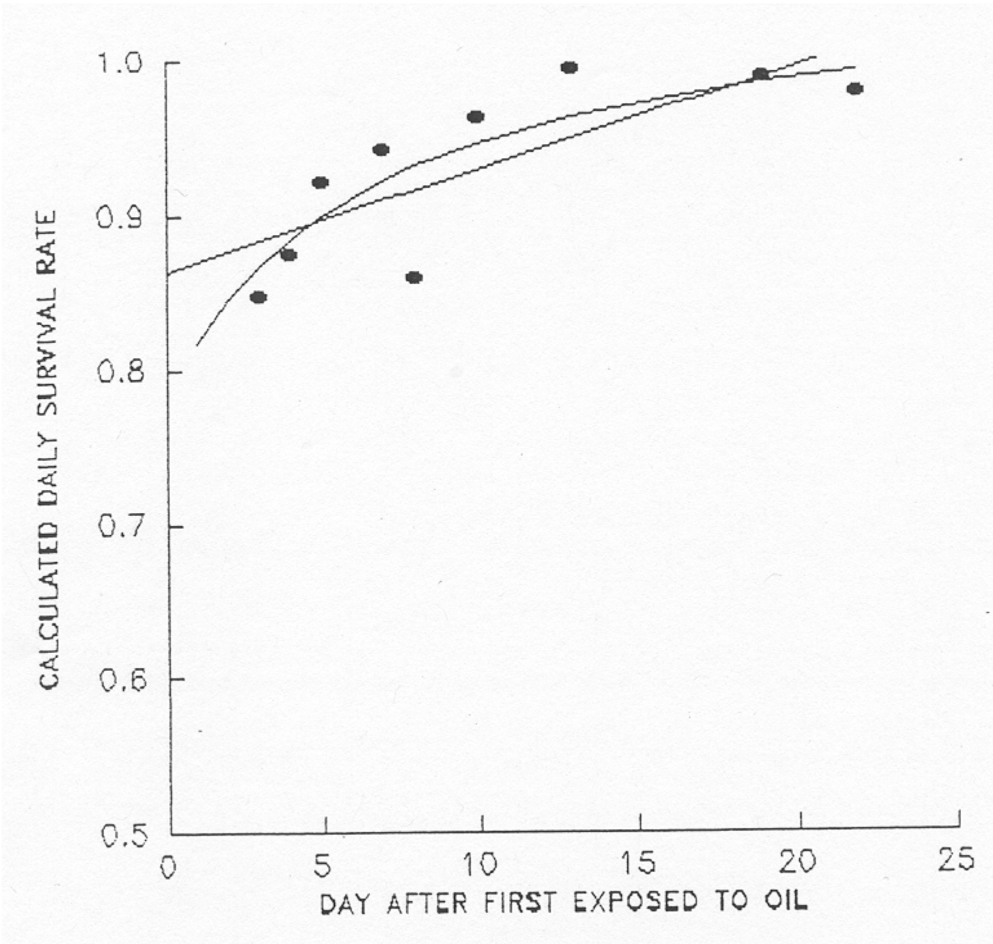


Figure 6. “Survivorship curve” for 109 sea otters first exposed to oil on approximately day 18-20 of EVOS off the Kenai Peninsula and subsequently captured.

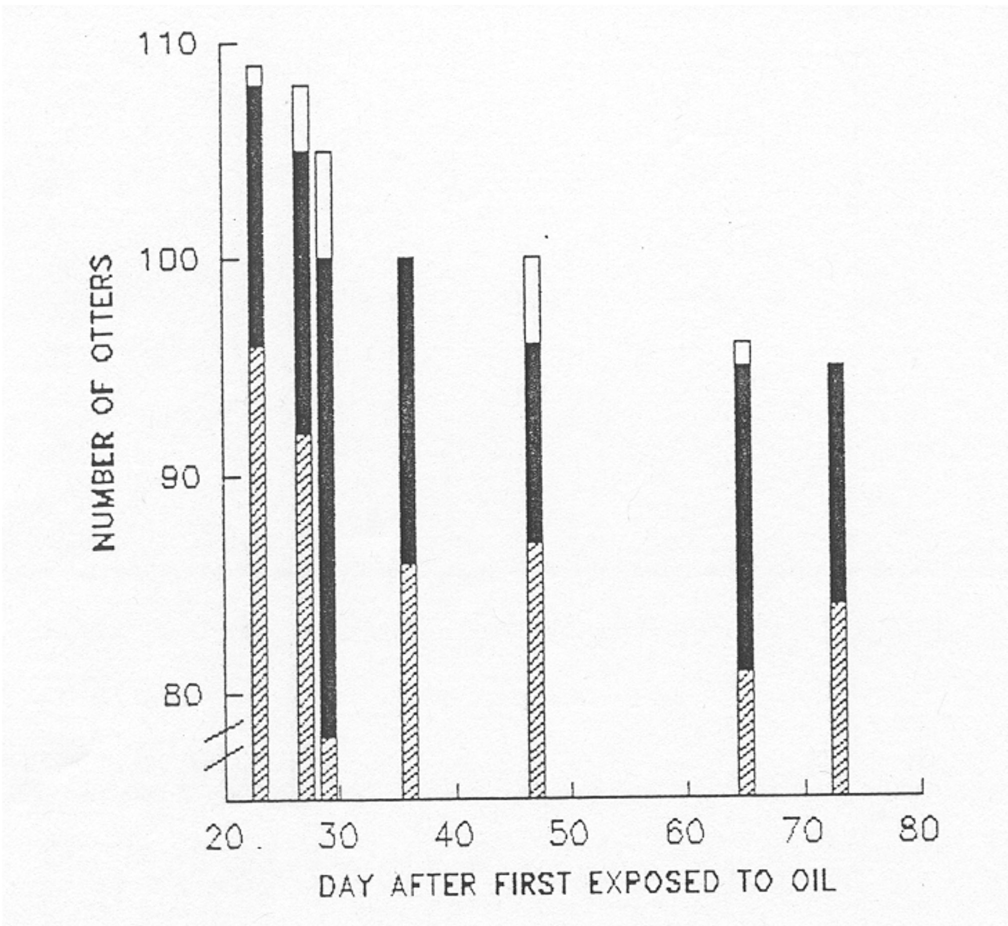


Table 4. Calculations used in estimating daily survival rates for 109 captured sea otters that were first exposed to oil on approximately day 20 of EVOS on Kenai Peninsula.

x	N_x	N_{x+1}	i	d_x (c_x)	$s_{i,x}$	s_x	X
23	109	108	1	1 (13)	.9907	.9907	23
27	108	105	4	3 (16)	.9722	.9929	25
29	105	100	2	5 (27)	.9523	.9759	28
35	100	100	6	0 (14)	1.0	1.0	32
46	100	96	11	4 (13)	.9600	.9963	41
64	96	95	18	1 (15)	.9895	.9994	55
73	95	95	9	0 (11)	1.0	1.0	68

COLUMN DEFINITIONS:

x Number of days exposed to oil.
N_x Number of animals alive on day x.
N_{x+1} Number of animals alive on day x+l.
i Number of days in interval between successive capture dates.
c_x Number of animals captured on day x.
d_x Number of animals captured on day x that will die.
$s_{i,x}$ Survival rate for interval i, beginning on day x.
s_x Daily survival rate in interval i ($s_i^{1/i}$).
X Day at which s_x applies (midpoint of interval i).

Figure 7. Calculated daily survival rates for 109 sea otters first exposed to oil on approximately day 18-20 of EVOS off the Kenai Peninsula and subsequently captured. Linear regression is not significant.

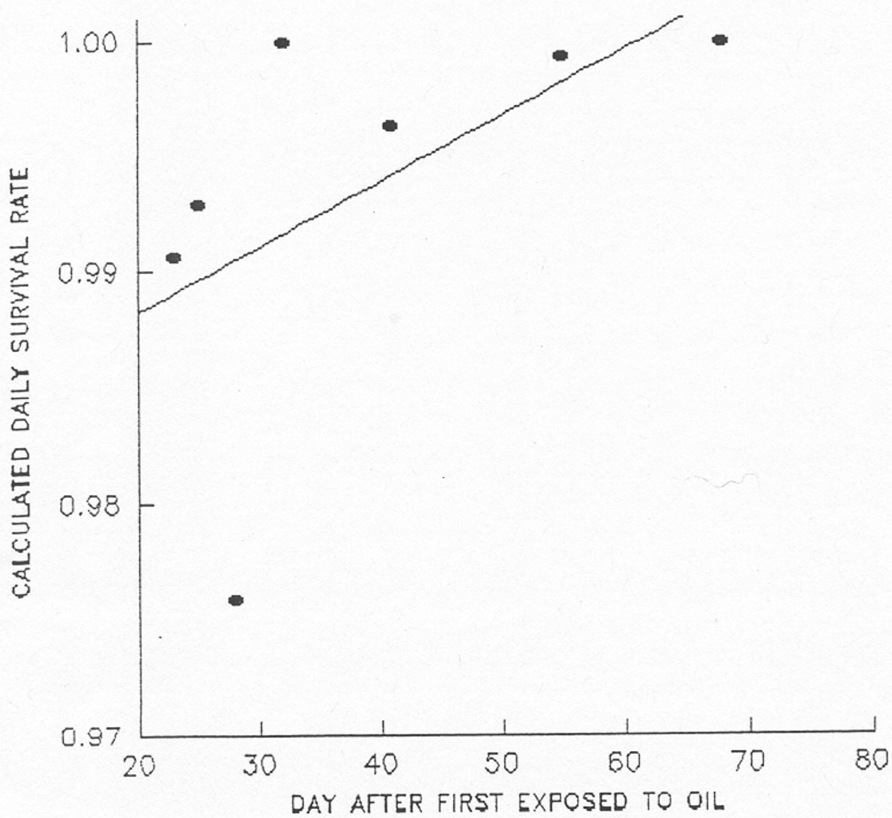


Figure 8. Calculated daily survival rates for 214 sea otters captured in rescue efforts after EVOS as a function of the age of the oil they were exposed to. Solid regression line is the "Michaelis Menton" relationship, dashed line is the log transformation.

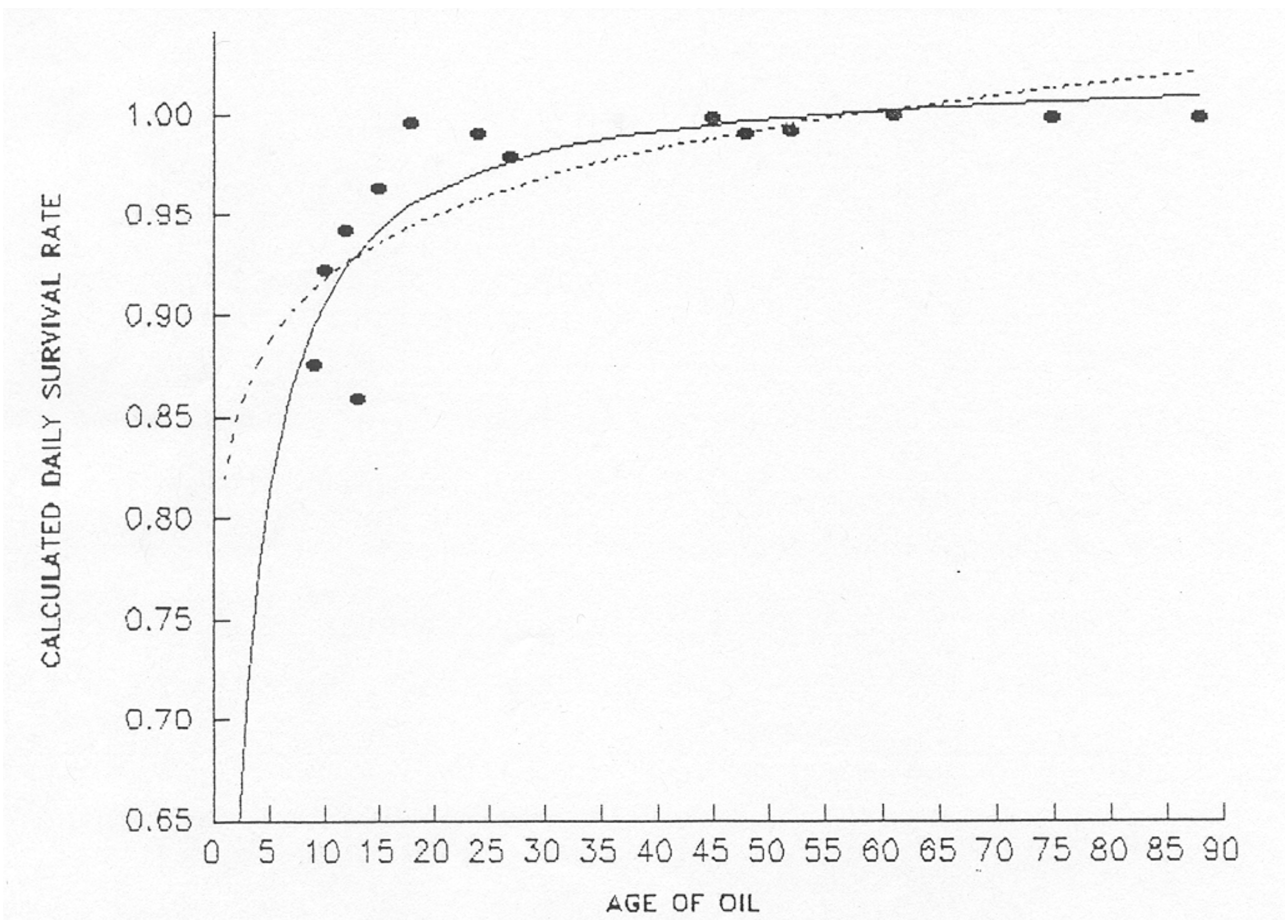
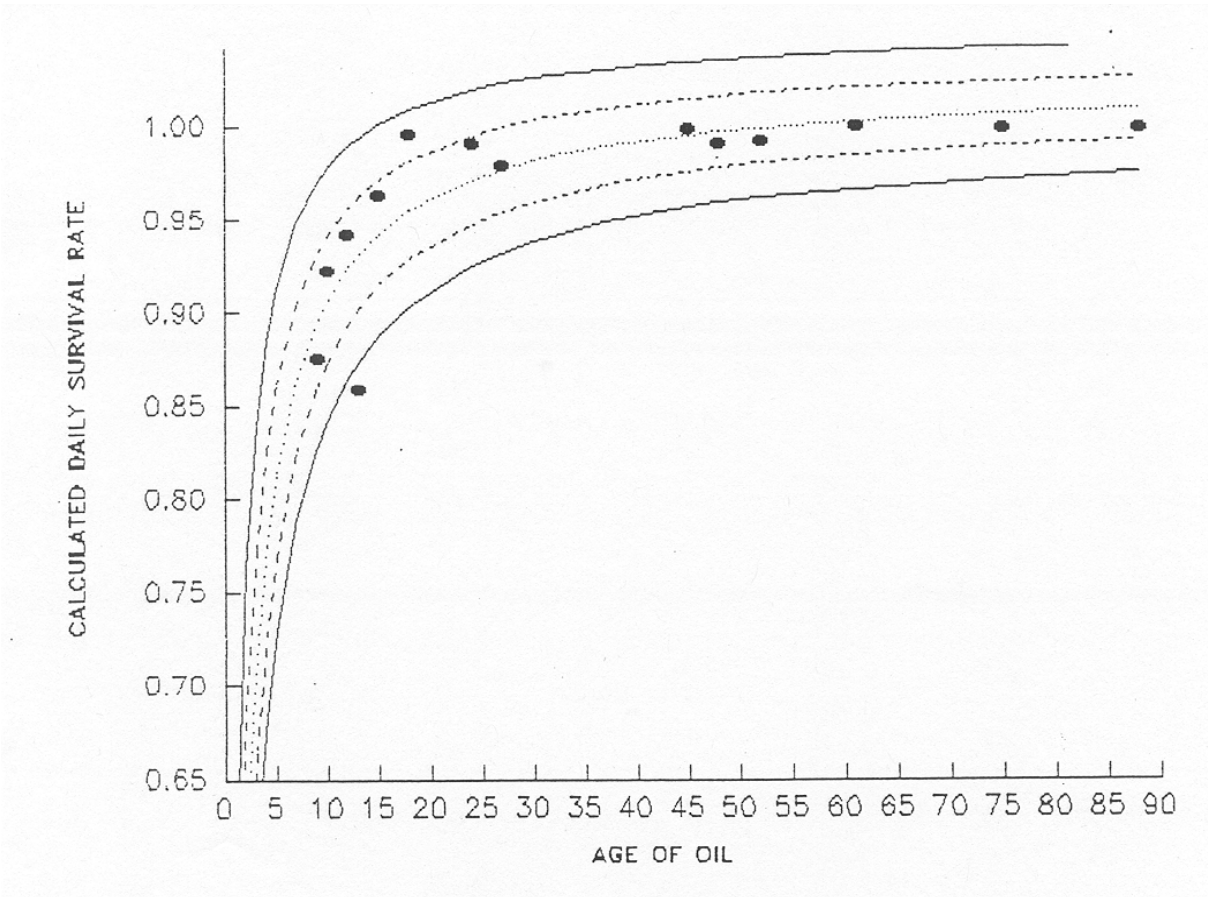


Figure 9. “Michaelis-Menton” regression relationship for daily survival rates of 214 sea otters captured in rescue efforts after EVOS as a function of the age of the oil they were exposed to. Dotted line is median estimate, dashed lines are +/- 1 standard error, solid lines are +/- 2 standard errors.



APPENDIX

Listing of raw data from N.R.D.A. relational data base of sea otters captured in rescue operations after EVOS, used in the analysis of mortality due to the oil spill.

KEY:
Oil = Light, Medium, Heavy, or None ... amount of oil on pelt at capture.
Fate = Died, Euthanized; R,V,X,H,Z ... survived.

Serial Number	Sex	Date of Capture	Location of Capture	Oil	Fate	Age
VZ-126	F	04 15 89	2 Mi N. Horseshoe Bay Latouche	M	Z	ADT
VZ-013	M	04 01 89	APPLEGATE	H	D	JUV
VZ-012		04 01 89	APPLEGATE	H	D	.
VZ-003	U	03 31 89	Applegate Rocks	H	D	.
VZ-015	M	04 01 89	Applegate Rocks	H	D	.
VZ-005	F	03 31 89	Applegate Rocks	H	Z	.
VZ-004	F	03 31 89	Applegate Rocks	H	Z	.
VZ-016	M	04 01 89	Applegate Rocks	H	D	.
VZ-014		04 01 89	Applegate Rocks	H	D	.
VZ-007	F	03 31 89	APPLEGTE	H	D	.
VZ-148	M	04 29 89	Bainbridge Is	L	R	ADT
VZ-075	F	04 06 89	Bay of Isles, Knight Is.	L	D	JUV
VZ-122	M	04 13 89	Bay of Isles KNIGHT I	N	R	ADT
VZ-091	F	04 08 89	BAY OF ISLES Knight Is.	L	Z	.
VZ-152	M	04 29 89	Berger Bay	H	R	ADT
SW-020	F	05 05 89	BOOT LEG BAY	U	H	.
SW-016	M	05 04 89	Bootleg Bay	M	X	.
SW-0l4	M	05 04 89	Bootleg Bay	M	X	.
SW-024	F	05 05 89	BOOTLEG BAY	U	H	.
SW-013	F	05 04 89	Bootleg Bay	M	H	.
SW-017	F	05 04 89	Bootleg Bay	L	R	.
SW-015	F	05 04 89	Bootleg Bay	L	R	.
SW-172	M	07 23 89	Chignik	N	Z	PUP
VZ -123	M	04 15 89	Chiswell Natoa Is	L	R	ADT
VZ-111	F	04 09 89	CRAB BAY	H	D	ADT
VZ-140	M	04 20 89	CRAB BAY, Evans Is	L	R	ADT
VZ-137	M	04 20 89	CRAB BAY, Evans Is	L	R	.
VZ-141	F	04 20 89	CRAB BAY, Evans Is	L	D	ADT
VZ-138	M	04 20 89	CRAB BAY, Evans Is	L	R	ADT
VZ-139	M	04 20 89	CRAB BAY, Evans Is	L	R	ADT
VZ-006	F	03 31 89	Elinore Island	H	D	.
VZ-143	F	04 22 89	Elrington I., Elrington Pass	M	R	JUV
VZ-l00	F	04 08 89	EVANS IS, Sawmill Bay	M	D	ADT
VZ-120	F	04 13 89	Ewan Bay, Delenia Is	L	R	ADT
VZ-047	F	04 04 89	FLEMING	L	D	JUV
VZ-046	M	04 04 89	FLEMING	L	R	ADT
VZ-048	M	04 04 89	FLEMING	L	R	ADT
VZ-045	F	04 04 89	FLEMING	M	D	ADT
VZ-044	F	04 02 89	Fleming Island	L	Z	PUP
VZ-049	F	04 04 89	Fleming OR Evans Is.	M	D	ADT
VZ-050	F	04 04 89	Fleming OR Evans Is.	L	D	ADT
SW-102	F	05 10 89	From Homer, Flat Island Off En	N	Z	PUP

SW-163	F	07	05	89	Frount Pt. (Tonsina Bay)	N	E	.
VZ-057	F	04	05	89	Gibbon Anchorage	U	E	ADT
SW-103	F	05	20	89	Granite Passage	L	D	.
VZ-023	F	04	01	89	GREEN IS	H	Z	ADT
VZ-035	M	04	02	89	GREEN IS	H	E	JUV
VZ-043	F	04	03	89	GREEN IS	M	D	JUV
VZ-010		04	01	89	GREEN IS	H	D	.
VZ-024	M	04	01	89	GREEN IS	H	D	ADT
VZ-032	F	04	02	89	GREEN IS	H	R	ADT
VZ-036	F	04	02	89	GREEN IS	H	Z	ADT
VZ-008	M	03	31	89	GREEN IS	H	D	.
VZ-033	U	04	02	89	GREEN IS	U	D	.
VZ-011	F	04	01	89	GREEN IS	L	D	JUV
VZ-019	F	04	01	89	GREEN IS	H	D	AGD
VZ-029	M	04	02	89	GREEN IS	H	R	ADT
VZ-026	F	04	01	89	GREEN IS	H	Z	ADT
VZ-034	M	04	02	89	GREEN IS	H	D	ADT
VZ-041	F	04	03	89	GREEN IS	H	D	ADT
VZ-018	F	04	01	89	GREEN IS	H	D	ADT
VZ-030	M	04	01	89	GREEN IS	H	R	ADT
VZ-028		04	01	89	GREEN IS	H	D	ADT
VZ-022	U	04	01	89	GREEN IS	H	D	.
VZ-017	U	04	01	89	GREEN IS	H	D	ADT
VZ-020	U	04	01	89	GREEN IS	H	D	.
VZ-021	F	04	01	89	GREEN IS	H	D	ADT
VZ-027	F	04	01	89	GREEN IS	H	Z	JUV
VZ-031	F	04	02	89	GREEN IS	H	D	ADT
VZ-038	F	04	02	89	GREEN IS	H	D	ADT
VZ-009		04	01	89	GREEN. IS	H	D	.
VZ-025		04	02	89	GREEN IS	H	D	.
VZ-131	F	04	17	89	GREEN IS, Gibbon Anch	L	X	ADT
VZ-040	F	04	03	89	GREEN IS, Gibbon Anch	H	D	ADT
VZ-132	F	04	17	89	GREEN IS, Outside Gibbon Anch	H	Z	ADT
VZ-042	F	04	03	89	Green Island, Gibbon Anch	H	D	ADT
SW-160	M	06	25	89	Hardover Pt.	N	D	.
VZ-146	M	04	27	89	Hardover Pt Nuka I.	L	R	JUV
VZ-071	F	04	05	89	Herring Bay	U	D	ADT
VZ-064	F	04	05	89	Rerring Bay	H	D	ADT
VZ-Q70	F	04	05	89	Herring Bay	H	E	ADT
VZ-063	F	04	05	89	Herring Bay	H	D	ADT
VZ-072	F	04	05	89	Herring Bay, Knight Is	M	Z	ADT
VZ-068	F	04	05	89	Herring Bay, Knight I.s	H	R	ADT
VZ-073	F	04	05	89	Herring Bay, Knight Is.	L	E	ADT
VZ-069	F	04	05	89	Herring Bay, Knight Is.	M	D	ADT
VZ-112	F	04	09	89	Herring Bay, Knight Is.	H	E	ADT
VZ-066	F	04	05	89	Herring Bay, Knight Is.	M	D	ADT
VZ-062	M	04	05	89	Hogan Bay, Knight Is.	L	R	ADT
VZ-055	M	04	04	89	Hogan Bay, Knight Island	L	D	ADT
VZ-054	F	04	04	89	Hogan Bay, Knight Island	H	D	JUV
VZ-056	M	04	04	89	Hogan Bay, Knight Island	L	D	ADT
VZ-092	M	04	07	89	HorshoeBay Latouche Is	H	R	ADT
VZ-037	F	04	02	89	Iktua Bay	L	D	JUV

VZ-058	F	04	05	89	Iktua Bay	U	D	ADT
VZ-l19	M	04	13	89	IKTUA Bay, Evans Is	L	R	ADT
VZ-106	F	04	09	89	IKTUA Bay, Evans is	L	D	ADT
VZ-114	F	04	10	89	IKTUA Bay, Evans Is	L	X	ADT
VZ-118	F	04	13	89	IKTUA Bay, Evans Is	L	D	ADT
VZ-116	M	04	10	89	IKTUA Bay, Evans Is	L	Z	ADT
VZ-104	M	04	09	89	IKTUA Bay, Evans Is	L	R	ADT
VZ-115	F	04	10	89	IKTUA Bay, Evans Is	L	Z	ADT
VZ-105	F	04	09	89	Iktua Bay Evans Is	N	R	ADT
VZ-121	M	04	13	89	Ingot Is, PWS	N	D	.
SW-158	F	06	23	89	Island #1, Rocky Bay	L	R	.
SW-124	F	05	31	89	Island #1, Rocky Bay	L	R	.
VZ-002	M	03	31	89	KNIGHT I	H	D	.
VZ-128	F	04	17	89	KNIGHT I, Herring Bay	L	R	ADT
VZ-135	F	04	19	89	KNIGHT I, Marsha Bay	H	D	ADT
VZ-129	F	04	17	89	KNIGHT I, SE Herring Bay	M	R	ADT
VZ-076	F	04	06	89	KNIGHT I, South end	U	E	ADT
VZ-082	F	04	06	89	KNIGHT I, SW	L	Z	.
VZ-094	F	04	07	89	Knight Is.	H	D	ADT
SW-174	M	07	26	89	Kodiak (Larson Bay)	N	E	JUV.
SW-138	M	06	14	89	Kodiak, Foul Bay	U	E	.
SW-137	F	06	14	89	Kodiak, Foul Bay	L	H	.
SW-131	F	06	10	89	Kodiak, Larson Bay	N	Z	PUP
SW-149	F	06	19	89	Kodiak, Ouzinkie	N	E	.
SW-177	F	08	21	89	Kodiak, Ouzinkie	N	Z	PUP
SW-176	M	07	31	89	KODIAK, Sumner Strait	N	Z	PUP
SW-114	M	05	24	89	Kodiak, Uyak Bay	N	H	.
SW-116	F	05	24	89	Kupreanoff Straight	L	R	.
SW-120	F	05	25	89	Kupreanoff Straights	L	E	.
SW-115	F	05	24	89	Kupreanoff Straights	L	E	.
SW-119	F	05	25	89	Kupreanoff Straights	L	H	.
SW-113	F	05	23	89	Kupreanoff Straights	L	H	.
SW-122	M	05	25	89	Kupreanoff Straights	L	H	.
SW-123	F	05	25	89	Kupreanoff Straights	L	H	.
SW-112	F	05	23	89	Kupreanoff Straights	L	H	.
SW-121	F	05	25	89	Kupreanoff Straights	L	H	.
VZ-124	M	04	16	89	LATOUCHE	L	R	ADT
VZ-125	F	04	15	89	LATOUCHE Is, Horseshoe Bay	L	R	ADT
VZ-108	M	04	09	89	LATOUCHE Is, Nontgomery	L	R	ADT
VZ-117	M	04	11	89	LATOUCHE Is, SW	L	Z	ADT
VZ-097	F	04	07	89	Latouche Is.	L	R	ADT
VZ-156	F	05	29	89	Little Bay, Knight Is	N	D	ADT
SW-164	F	07	05	89	Long Island (Tonsina Bay)	L	R	.
SW-162	F	07	05	89	Long Island (Tonsina Bay)	L	R	.
SW-161	F	07	05	89	Long Island (Tonsina Bay)	L	R	.
VZ-107	F	04	09	89	Main Bay Kenai Pen;	L	D	ADT
VZ-052	M	04	04	89	Mummy Bay	M	R	ADT
VZ-053	F	04	04	89	Mummy Bay	H	D	ADT
VZ-051	F	04	04	89	Mummy Bay	H	Z	JUV
VZ-081	M	04	06	89	N. Chenega Bay	L	E	ADT
VZ-039	M	04	03	89	N.W. tip Green Island	M	D	ADT
VZP154	F	05	03	89	N A	N	D	PUP

VZP142	F	04	22	89	N A	N	D	PUP
VZ-134	M	04	18	89	NATOA IS	M	D	ADT
VZ-130	M	04	17	89	NATOA IS	M	R	ADT
VZ-133	M	04	18	89	NATOA IS	L	R	ADT
VZ-144	M	04	22	89	New Chenega Hbr	L	R	ADT.
SW-167	F	07	06	89	NUKA BAY	L	R	.
SW-105	F	05	20	89	Nuka bay	U	E	.
SW-109	F	05	21	89	Nuka Bay, East Arm	U	E	.
SW-165	F	07	06	89	NUKA BAY, East Arm	U	H	.
SW-166	F	07	06	89	NUKA BAY, East Arm	N	H	.
VZ-127	F	04	16	89	NW SQUIRE I	H	R	ADT
SW-173	M	07	25	89	Oizinkie, Kodiak	N	Z	PUP
VZ-136	M	04	19	89	ORCA INL	U	D	AGD
VZ-083	M	04	06	89	PERRY IS, N	U	D	PUP
SW-153	M	06	21	89	Picnic Bay	L	H	.
SW-045	F	05	07	89	Picnic Harbor	N	R	ADT
VZ-147	F	04	27	89	Port GRAHAM	N	D	PUP
VZ-086	F	04	07	89	Powder Pt. NW Latouche Is.	U	R	ADT
VZ-102	F	04	08	89	Pr Wales	L	D	.
VZ-085	F	04	07	89	Pr Wales Evans Is.	M	D	ADT
VZ-087	M	04	07	89	Pr Wales Evans Is.	U	D	JUV
VZ-101	M	04	08	89	Prince Wales	L	X	JUV
VZ-088	F	04	07	89	PRINCE Wales Is.	U	D	ADT
VZ-096	F	04	08	89	Prince Wales Pass	L	R	ADT
VZ-103	M	04	08	89	Prince Wales Evans Is.	L	D	ADT
SW-175	F	07	28	89	PYE ISLAND	N	Z	PUP
SW-152	M	06	20	89	Rock entrance of Rocky River	L	H	.
SW-067	F	05	11	89	Rocky Bay	L	D	.
SW-061	F	05	11	89	Rocky Bay	M	X	ADT
SW-076	F	05	11	89	Rocky Bay	M	D	.
SW-039	F	05	07	89	Rocky Bay	L	R	ADT
SW-028	F	05	05	89	ROCKY BAY	L	H	.
SW-155	F	06	21	89	Rocky Bay	M	R	.
SW-l59	F	06	23	89	Rocky Bay	U	R	.
SW-070	M	05	11	89	Rocky Bay	U	R	.
SW-026	F	05	05	89	ROCKY BAY	U	H	.
SW-027	F	05	05	89	ROCKY BAY	L	H	.
SW-093	F	05	18	89	Rocky Bay	L	H	.
SW-037	F	05	07	89	ROCKY BAY	U	H	.
SW-036	F	05	07	89	ROCKY BAY	U	H	.
SW-l07	M	05	21	89	Rocky Bay	U	E	.
SW-068	F	05	11	89	Rocky Bay	L	R	.
SW-156	M	06	22	89	Rocky Bay	L	H	.
SW-101	F	05	19	89	Rocky Bay	U	H	.
SW-080	F	05	11	89	Rocky Bay	M	H	.
SW-062	F	05	11	89	Rocky Bay	L	H	.
SW-154	M	06	21	89	Rocky Bay	N	H	.
SW-079	F	05	11	89	Rocky Bay	L	H	.
SW-096	M	05	18	89	Rocky Bay	L	H	.
SW-069	F	05	11	89	Rocky Bay	M	H	.
SW-029	F	05	05	89	ROCKY BAY	M	H	.
SW-104	M	05	20	89	Rocky Bay	L	D	.

SW-100	F	05	19	89	Rocky Bay	U	H	.
SW-097	F	05	18	89	Rocky Bay	L	H	.
SW-094	M	05	18	89	Rocky Bay	L	H	.
SW-099	M	05	18	89	Rocky Bay	L	H	.
SW-091	F	05	18	89	Rocky Bay	L	H	.
SW-095	M	05	18	89	Rocky Bay	L	H	.
SW-063	F	05	11	89	Rocky Bay	U	H	.
SW-098	F	05	18	89	Rocky Bay	M	H	.
SW-150	F	06	19	89	Rocky Bay Island #1	L	H	.
SW-126	M	06	05	89	Rocky Bay, Island #1	L	H	.
SW-135	M	06	13	89	Rocky Bay, Island #1	L	D	.
SW-125	F	06	05	89	Rocky Bay, Island #1	L	D	.
SW-134	F	06	13	89	Rocky Bay, Island #1	L	H	.
SW-128	F	06	06	89	Rocky Bay, Island #14	L	R	.
SW-127	F	06	05	89	Rocky Bay, Island #3	L	D	.
SW-130	M	06	06	89	Rocky Bay, Island #4	L	H	.
SW-129	F	06	06	89	Rocky Bay, Island #4	L	H	.
SW-092	F	05	18	89	Rocky Bay	L	H	.
SW-157	F	06	23	89	Rocky River	L	R	.
VZ-090	M	04	08	89	Sawmill Bay Latouche Is.	L	R	ADT
SW-117	F	05	25	89	Seal Island	N	H .	.
SW-118	M	05	25	89	Seal Island	N	H	.
VZ-099	M	04	08	89	Shelter Bay, Knight Is.	L	D	ADT
SW-008	F	05	02	89	SKAXUNDS	L	D	.
VZ-001	M	03	30	89	SMITH IS	H	D	.
VZ-077	F	04	06	89	Snug Hbr, Knight Is.	H	D	ADT
VZ-079	F	04	06	89	Snug Hbr, Knight Is.	L	D	ADT
VZ-109	M	04	09	89	Snug Hbr KNIGHT I	M	D	ADT
VZ-110		04	09	89	Snug Hbr KNIGHT I	H	E	.
SW-057	F	05	11	89	South Bay Natoa Island	M	H	.
SW-110	F	05	22	89	Spiridon Bay, Kodiak I	U	H	.
SW-044	M	05	07	89	TAYLOR BAY	L	H	.
SW-043	F	05	07	89	TAYLOR BAY	L	H	.
SW-041	F	05	07	89	Tonsina Bay	U	R	ADT
SW-042	M	05	07	89	TONSINA BAY	L	H	.
SW-034	F	05	05	89	Tonsina Bay	L	R	ADT
SW-032	F	05	05	89	TONSINA BAY	U	H	.
VZ-145	F	04	27	89	TONSINA BAY	L	R	JUV
VZ-150	F	04	29	89	TONSINA Bay	L	R	ADT
SW-001	F	05	01	89	TONSINA BAY	N	D	.
SW-170	M	07	17	89	Tonsina Bay	N	E	.
SW-004	F	05	01	89	Tonsina Bay	N	Z	PUP
SW-009	F	05	03	89	TONSINA BAY	L	H	.
SW-003	F	05	01	89	TONSINA BAY	N	H	.
VZ-153	F	04	29	89	Tonsina Bay	L	R	ADT
SW-010	F	05	03	89	TONSINA BAY	L	H	.
SW-031	F	05	05	89	TONSINA BAY	L	H	.
SW-005	F	05	01	89	TONSINA BAY	L	H	.
VZ-151	F	04	29	89	Tonsina Bay	L	R	ADT
SW-002	F	05	01	89	TONSINA BAY	N	R	.
SW-030	M	05	05	89	Tonsina Bay	L	X	ADT
SW-007	F	05	01	89	TONSINA BAY	L	H	.

SW-011	F	05	03	89	TONSINA BAY	L	H	.
SW-169	M	07	08	89	Tonsina Bay	L	H	.
SW-168	F	07	08	89	Tonsina Bay	N	H	.
VZ-149	F	04	29	89	Tonsina Bay	M	X	ADT
SW-006	F	05	01	89	Tonsina Bay	L	H	.
SW-025	M	05	05	89	WINDY BAY	U	H	.
SW-050	F	05	10	89	Windy Bay	L	D	.
SW-089	F	05	17	89	Windy Bay	L	R	.
SW-171	M	07	22	89	WINDY BAY	L	R	.
SW-147	F	06	17	89	Windy Bay	U	H	.
SW-059	F	05	11	89	Windy Bay	U	R	ADT
SW-077	F	05	11	89	Windy Bay	M	E	.
SW-048	F	05	10	89	Windy Bay	L	E	.
SW-047	F	05	10	89	Windy Bay	U	R	ADT
SW-049	F	05	10	89	Windy Bay	L	D	.
SW-018	M	05	05	89	WINDY BAY	N	H	.
SW-065	M	05	11	89	Windy Bay	H	R	ADT
SW-055	F	05	10	89	Windy Bay	M	X	ADT
SW-142	F	06	17	89	Windy Bay	N	R	.
SW-082	F	05	11	89	Windy Bay	M	R	.
SW-040	F	05	07	89	Windy Bay	L	R	ADT
SW-143	F	06	17	89	Windy Bay	N	R	.
SW-012	F	05	03	89	WINDY BAY	L	H	.
SW-035	F	05	05	89	Windy Bay	L	R	ADT
SW-019	F	05	05	89	WINDY BAY	U	H	.
SW-084	F	05	11	89	Windy Bay	L	R	ADT
SW-023	F	05	05	89	WINDY BAY	U	H	.
SW-051	F	05	10	89	Windy Bay	L	H	.
SW-021	F	05	05	89	WINDY BAY	U	D	.
SW-146	F	06	17	89	Windy Bay	L	R	.
SW-075	F	05	11	89	Windy Bay	L	D	.
SW-145	F	06	17	89	Windy Bay	U	R	.
SW-033	F	05	05	89	Windy Bay	N	R	ADT
SW-052	F	05	10	89	Windy Bay	L	H	.
SW-085	F	05	17	89	Windy Bay	N	H	.
SW-087	F	05	17	89	Windy Bay	L	H	.
SW-139	F	06	17	89	Windy Bay	U	H	.
SW-081	F	05	11	89	Windy Bay	L	H	.
SW-058	F	05	11	89	Windy Bay	L	H	.
SW-108	M	05	21	89	Windy Bay	U	H	.
SW-064	F	05	11	89	Windy Bay	U	H	.
SW-060	F	05	11	89	Windy Bay	L	H	.
SW-141	F	06	17	89	Windy Bay	L	H	.
SW-083	M	05	11	89	Windy Bay	U	H	.
SW-148	F	06	17	89	Windy Bay	N	Z	PUP
SW-086	F	05	17	89	Windy Bay	L	H	.
SW-151	M	06	20	89	Windy Bay	L	H	.
SW-144	F	06	17	89	Windy Bay	N	H	.
SW-053	F	05	10	89	Windy Bay	L	H	.
SW-140	F	06	17	89	Windy Bay	U	H	.
SW-056	F	05	10	89	Windy Bay	M	H	.
SW-071	F	05	11	89	Windy Bay	L	H	.

SW-072	F	05	11	89	Windy Bay	L	H	.
SW-106	M	05	21	89	Windy Bay	N	Z	PUP
SW-074	F	05	11	89	Windy Bay	H	H	.
SW-088	F	05	17	89	Windy Bay	L	H	.
SW-022	F	05	05	89	WINDY BAY	U	H	.
SW-066	F	05	11	89	Windy Bay	U	H	.
SW-038	M	05	07	89	WINDY BAY	M	H	.
SW-078	M	05	11	89	Windy Bay	L	D	.
SW-073	F	05	11	89	Windy Bay	U	H	.
SW-054	F	05	10	89	Windy Bay	M	H	.
SW-133	F	06	13	89	Windy Bay, Kelp Bed 0	N	Z	PUP
SW-136	F	06	13	89	Windy Bay, Kelp Bed 0	L	H	.
SW-132	F	06	13	89	Windy Bay, Kelp Bed 0	L	H	.
SW-090	F	05	17	89	Wooded Island, Kodiak	L	H	.

Appendix D: Population Status of the Southern Sea Otter

Population Status of the California Sea Otter*

J.A. Estes and B.B. Hatfield

Biological Resources Division
U.S. Geological Survey

4 November 1998

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INTRODUCTION

The geographical range of the sea otter (*Enhydra lutris*) extends across the North Pacific Ocean from about the central Pacific coast of Baja California, Mexico, to northern Japan. Prior to the Pacific maritime fur trade, which began with the discovery of Alaska and the Aleutian Islands by the Bering Expedition in the mid-1700s, high density sea otter populations probably occurred more or less continuously throughout this region, but the species was systematically hunted to the brink of extinction by the end of the 19th century. Sea otters were afforded protection from further take in 1911, at which time about a dozen remnant colonies survived. One of these remnant colonies occurred near Bixby Creek along the then remote Big Sur coastline.

With protection, the surviving colonies began to recover. While early records of recovery are necessarily sparse, the population in central California clearly has increased at a slower rate than all or most others (Estes 1990). For instance, a naturally reestablished population at Attu Island (in the western Aleutian archipelago) and populations reestablished through reintroductions in Washington State, Vancouver Island, and southeast Alaska, all increased at 17-20% yr^{-1}, which is about the theoretical maximum rate of population growth for the species. Other populations in Alaska and Asia seem to have recovered at about the same rate. The California sea otter population, in contrast, has recovered at about 4 to 6% yr^{--1} at best.

While records of initial population size and early growth are spotty because of a lack of information prior to World War II and varying survey methods thereafter, the data are sufficient to demonstrate that growth rate of the California sea otter population was always slow, even early in this century. Nonetheless, both the range and population size marched steadily upward until about the mid-1970s, at which time numbers began to decline. As information from field studies accumulated, it became evident that California sea otters were being lost to incidental entanglement in a coastal set-net fishery and there was increasing concern that this was the cause of the decline. Loss estimates to the fishery made by the California Department of Fish and Game added credence to that possibility (Wendell *et al.,* unpubl. CDF&G report). The State of California instituted a limited emergency closure of the set net fishery in 1982, followed by a range-wide 15 fathom closure in 1985, and the number of animals counted during annual surveys began to increase shortly thereafter (Riedman and Estes 1990, Estes 1990). A standardized survey method also was developed and put into use in 1982. Briefly, the new survey procedures involved counting animals twice annually (early autumn and late spring) from shore in accessible stretches of coastline, and from a fixed-wing aircraft in the remaining areas. The data from 1982 onward thus are not confounded by methodological change and have been used to assess population trends over the past 16 years. In addition to total population size, the number of dependent pups are noted in each survey. These data, in conjunction with findings from several more in-depth studies (Jameson and Johnson 1993, Riedman *et al.* 1994) are sufficient to assess female reproductive rates and changes in reproductive success of the California sea otter population through time.

During this same period, information has been obtained on sea otter mortality from beach-cast carcasses in a salvage program that has been variously organized and managed over the years by CDF&G, FWS, and BRD. As is the case with surveys of the living population, the methods and level of effort have varied through the years. Perhaps the most significant methodological change occurred in 1992 when necropsies of fresh otter carcasses were undertaken by trained veterinary pathologists from the National Wildlife Health Center in Madison, Wisconsin. This effort identified infectious disease as the ultimate cause of death in about 40 percent of the beach-cast carcasses for California--a significant finding because it helped explain the relatively low growth rate of the California sea otter population.

This White Paper was written at the request of the Ventura Field Office of the Fish and Wildlife Service following the movement of about 100 otters in spring of 1998 into the area near Government Point south of Point Conception. The redistribution was problematic because it created a management dilemma for the Fish and Wildlife Service. Government Point is in the “no-otter zone” established by Public Law 99-625, and the Service therefore is legally obligated to remove these animals. However, removal of so many otters might also have a detrimental effect on the parent population, listed as Threatened under the Endangered Species Act. Thus, compliance with one law would result in violation of the other. Our intent here is to provide Fish and Wildlife Service with an overview of the biological information needed to formulate a response plan. Specifically, we will 1) summarize the most recent data on distribution and abundance of the California sea otter population, from which we will assess current population status; 2) summarize data on numbers of beach-cast carcasses and cause of death in these animals; 3) discuss possible reasons for a recent change in population trends; 4) discuss the likely consequences of strict compliance with Public Law 99-625; and 5) identify future information needs. We will not analyze the data in detail, but rather identify what, in our judgement, are the high points and most relevant conclusions.

TRENDS IN POPULATION ABUNDANCE AND DISTRIBUTION

Information on the distribution and abundance of sea otters in California prior to 1990 is summarized by Riedman and Estes (1990). Although both range and numbers have increased during the 20th century, these variables are not well correlated. In particular, whereas population abundance has experienced several periods of decline, distribution evidently has not retracted during these periods.

Range delineation is somewhat arbitrary because individuals frequently wander well beyond the distributional limits of most of the population. Nonetheless, the geographic range of the California sea otter has expanded greatly since 1938, at which time most individuals occurred in the area between Bixby Creek in the north to Pfeiffer

Point in the south. As the population increased over subsequent decades, range expansion to the south was consistently more rapid than it was to the north. By the late 1980s, the California sea otter's range had increased to include the area between about Point Año Nuevo at the north and Point Sal at the south. Although the number of otters continued to increase through the mid 1990s, range expansion to the south slowed and to the north it essentially ceased during this period. By 1995, sea otters were commonly seen as far south as Point Arguello and in 1998 a substantial number of otters dispersed into the "no-otter zone" south of Point Conception.

Population abundance of the California sea otter has steadily increased through the twentieth century, except for two periods. By 1976 the population contained an estimated 1,789 individuals, but then declined to 1,443 by 1979 and to 1,372 by 1984. Standardized range-wide counts, undertaken in the spring and fall of each year, were initiated in 1982. The spring surveys have traditionally been used to assess population status since they are both consistently higher than the fall surveys in any given year and less variable among years. The number of animals counted during spring surveys remained essentially constant until 1985, increasing steadily thereafter until the mid-1990s (Fig. 1A & 1B). However, since 1996, the total number of animals counted in the spring surveys has progressively declined. This trend is evident in both the yearly counts (Fig. 1A) and in the same data plotted as 3-year running averages (Fig. 1B). Running averages were used to eliminate year-to-year vagaries in any given count, thus emphasizing overall trends. Trends in the spring counts thus indicate that the California sea otter population recently has declined. The fall counts show a similar pattern (Figs. 1C & 1D).

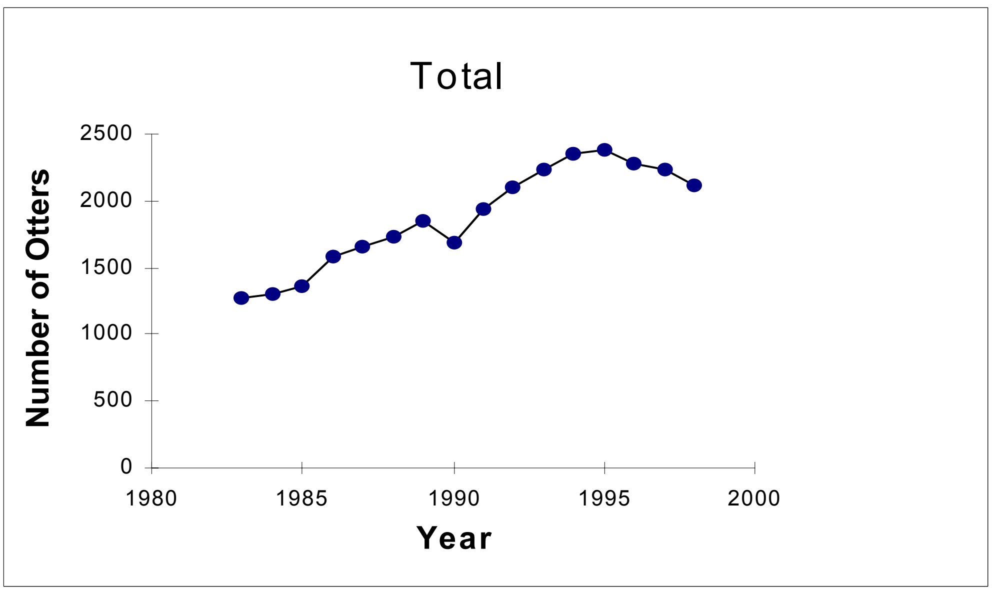

Figure 1A. The total number of sea otters counted from 1982 through 1998 during spring surveys.

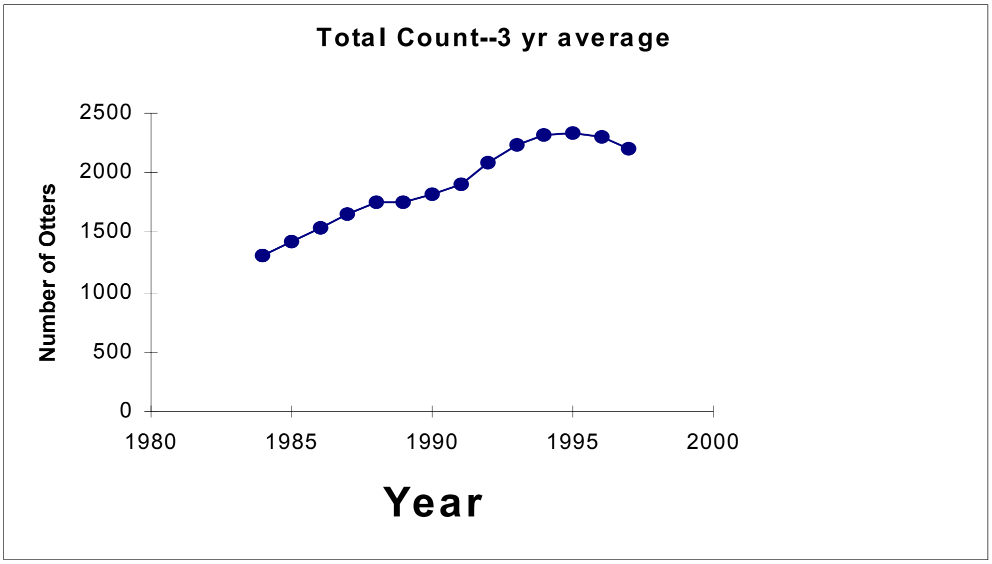

Figure 1B. Total number of sea otters counted during the spring surveys, plotted as 3-year running averages.

TRENDS IN MORTALITY

Our assessment of sea otter mortality in California is based on information obtained from beach-cast carcasses. Two measures are available: 1) the number of carcasses retrieved and 2) the cause of death in fresh carcasses. The number of carcasses recovered through time shows an overall pattern that is roughly consistent with population growth (Fig. 2). However, relative mortality patterns (measured by dividing the number of carcasses retrieved in a given year by the number of otters counted in the spring survey of that same year) indicate several departures from a time-constant relationship (Fig. 3). These data suggest further that mortality was roughly constant at about 5% yr^{-1} during the period of population increase (i.e., from about 1985 through 1994) but increased somewhat during periods of decline (i.e., the early 1980s and from 1995-1998). In sum, the available information suggests that the size of the California sea otter population has declined and mortality has increased over the past several years.

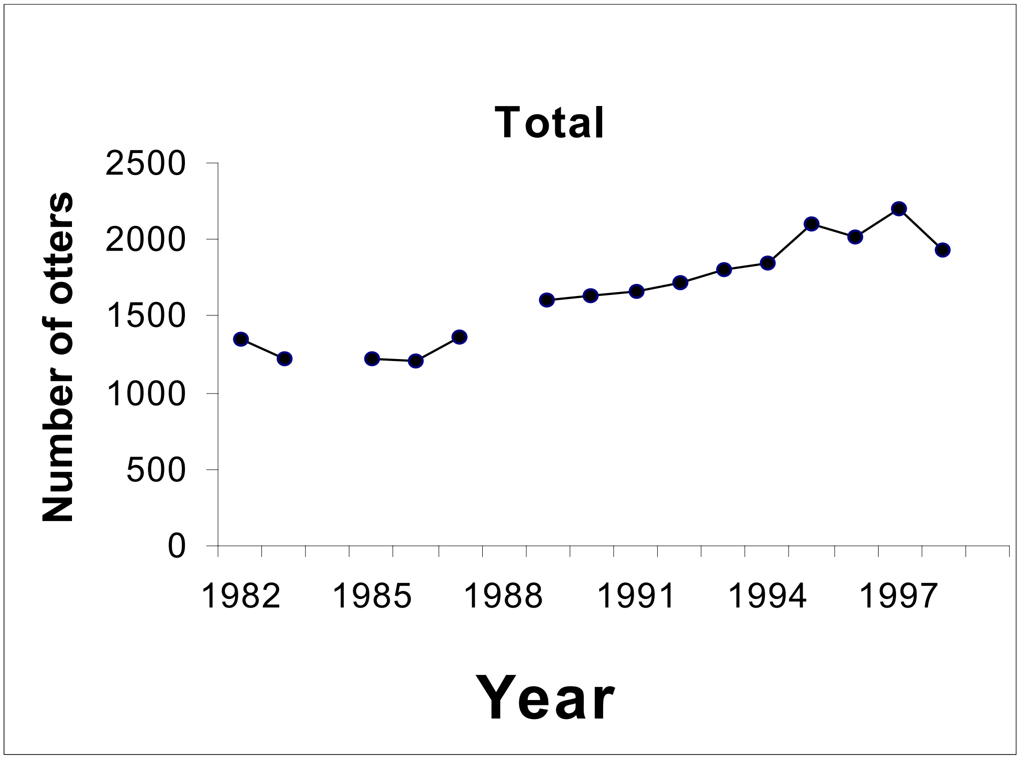

Figure 1C. Total number of sea otters counted from 1982 through 1997 in autumn surveys. Autumn surveys were not conducted in 1984 or 1988.

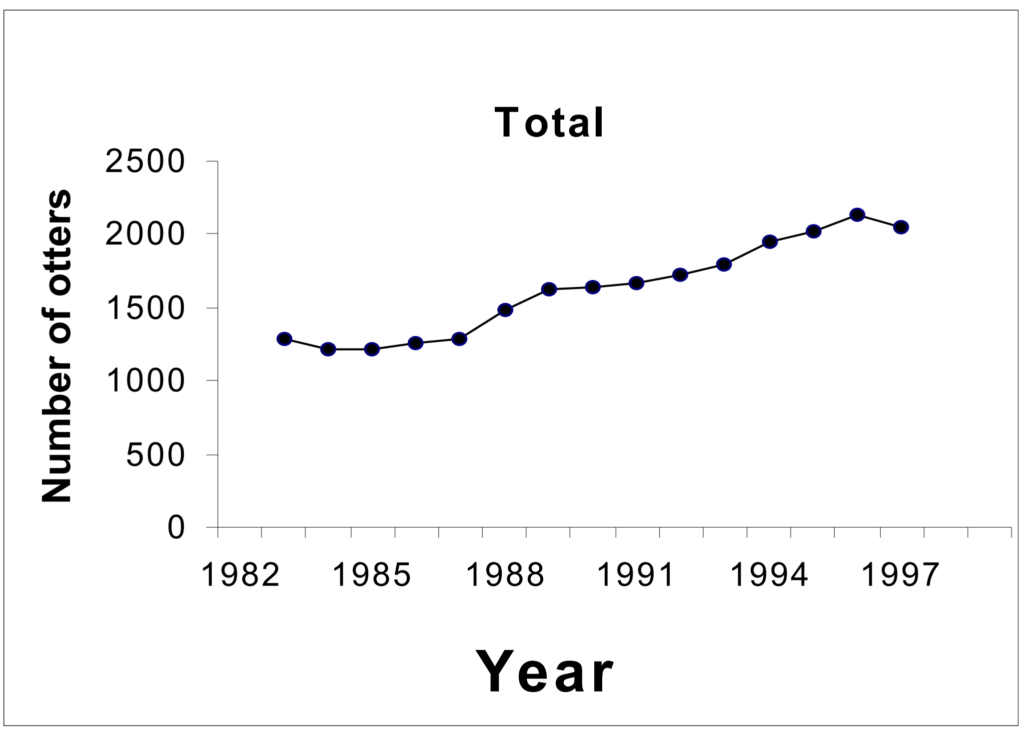

Figure 1D. Total number of sea otters counted in autumn surveys, plotted as 3-year running averages. No autumn surveys were conducted in 1984 and 1988; therefore years 1983-85 and 1987-89 are represented as 2-year averages.

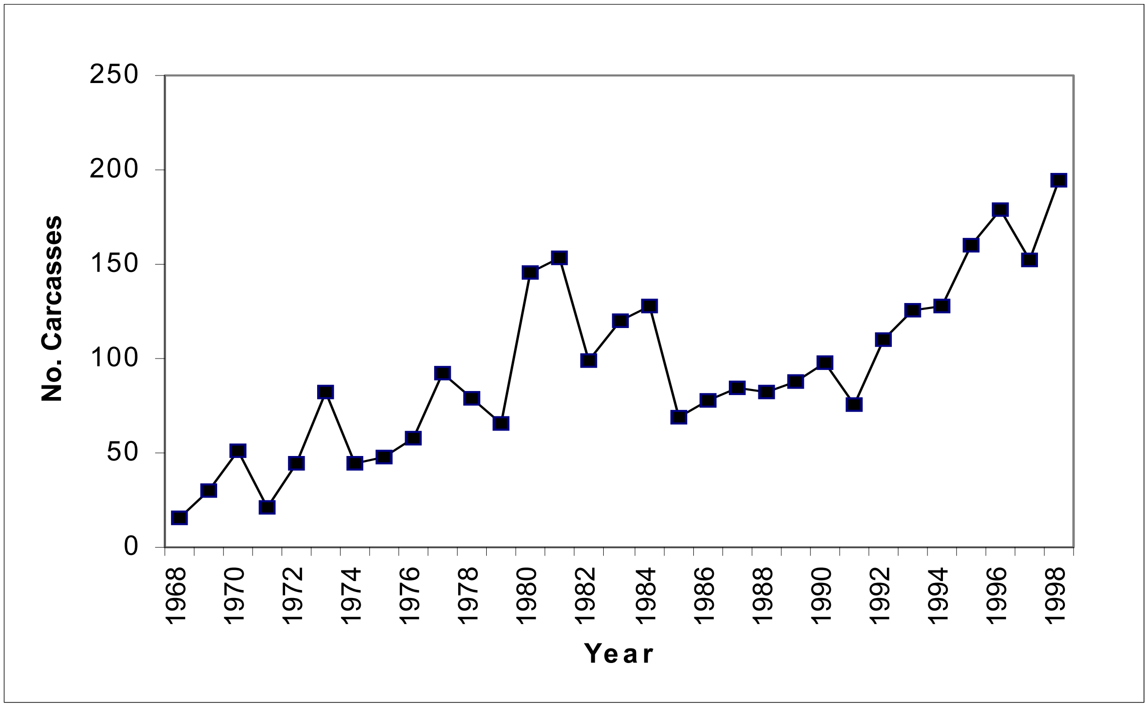

Figure 2. The number of beach-cast sea otter carcasses recovered by year from 1968 through 1998. Note that since 1998 is not yet over, the value was estimated by adding the number retrieved through September 1998 (172) to the most recent 10-year average number of carcasses recovered from October through December (22.9), for a total of 194.9.

Two explanations for increased mortality and reduced population abundance in the California sea otter have been suggested—infectious disease and incidental losses in coastal fishing gear. Because thorough necropsies have been done on fresh carcasses since 1992, it is possible to make a preliminary evaluation of the disease hypothesis. Inasmuch as the elevated mortality rate and declining abundance did not begin until about 1995, the incidence of infectious disease- induced mortality also should have increased concurrently if this were responsible for recent trend changes in the population. No changes in the rate of infectious disease are evident since 1992 (Fig. 4).

Nonetheless, two conclusions can be drawn about the influence of infectious disease on California sea otter populations. First, infectious disease must be an important factor in causing the slow growth rate, given that disease is responsible for roughly half of the deaths of animals obtained in the salvage program. Since the reproductive rate of California sea otters is comparable to that of other populations that are growing more rapidly, it follows that growth rate of the California population would be much higher in the absence of disease. The magnitude of this potential gain is unknown although it probably could be determined through population modeling. Second, the collective data suggest that the incidence of infectious disease may have been high throughout this century. The California sea otter population has never increased at more than about 5 % yr^{-1}, thus implying that mortality rate has not changed appreciably during the period of recovery. We also know that disease rate was high in the early 1990s, a time when the population was increasing at about 5 percent yr^{-1}. Therefore, if the rate of infectious disease has increased in recent years, some other source of mortality must have declined concurrently. Although such changes are conceivable, there is no reason to believe that they have occurred.

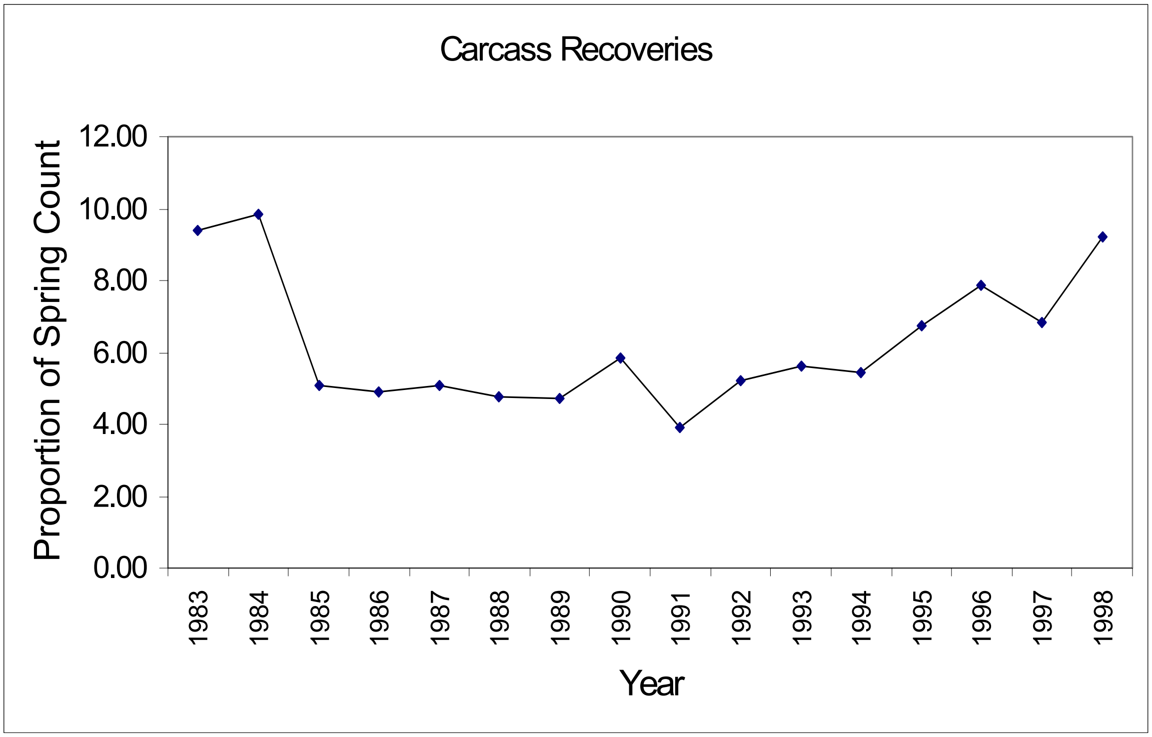

Figure 3. The relative number of sea otter carcasses retrieved by year. Proportions were determined by dividing the number of carcasses recovered by the number of otters counted in the spring surveys (x100).

While coastal pot fisheries are known to have intensified in recent years, and there are unconfirmed reports of otters having been killed by swimming into these pots for either their bait or targeted catch, we do not yet have sufficient information to evaluate this potential source of mortality. There is also a renewed concern about the incidental loss of sea otters in gill and trammel nets. The National Marine Fisheries has estimated the sea otter losses in central California have increased from near zero in 1995 to almost 50 individuals in 1998 (Karin Forney, NMFS, unpubl. data). Losses of this magnitude would significantly impact sea otter population trends.

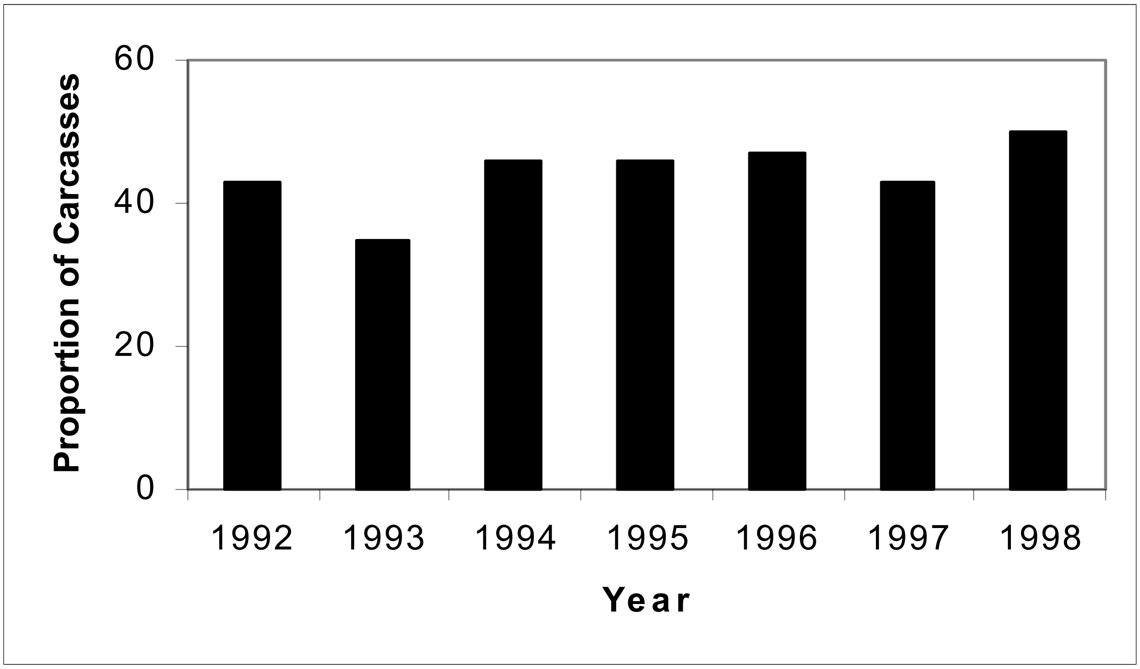

Figure 4. Proportion of sea otter carcasses necropsied at the National Wildlife Health Center that died of infectious or parasitic disease by year from 1992-1998. Two hundred and seventy one carcasses were examined, ranging from 65 in 1995 to 14 in both 1997 and 1998 (through July). These data should be treated as preliminary as diagnostic information on the most recent cases continues to be developed.

TRENDS IN REPRODUCTIVE SUCCESS

Reproduction has been studied in several sea otter populations (including California) by tagging known-age individuals and chronicling birth rate and pup survival rate from follow-up observations of the tagged animals. While the season of births and the probability of pup survival from birth to weaning vary by female age and population status, age-specific birth rates are virtually constant in all populations that have been studied. Several such studies, all completed prior to 1995, have been done on California sea otters (Siniff and Ralls 1989, Jameson and Johnson 1993, Riedman *et al.* 1994). There is no evidence for depressed reproduction from any of these studies.

A measure of reproductive success is also provided by the annual survey data, through the dependent pup counts. The pup to independent ratio varies considerably among years (Fig. 5). However, there is no obvious relationship between these measures and population trends.

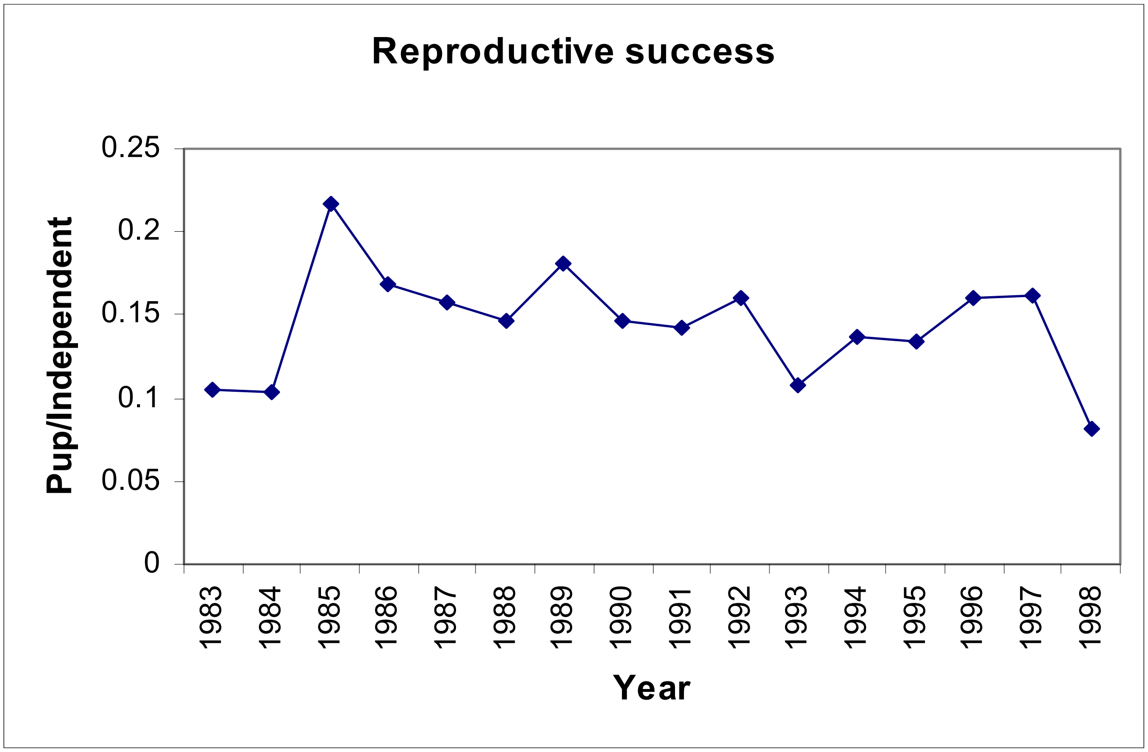

Figure 5. The ratio of dependent pups to independent sea otters as determined from the spring surveys done from 1983 through 1998.

Sea otters reproduce throughout the year and females typically come into estrous immediately after losing a pup (either from weaning or premature death). The low pup/independent ratios seen in the early 1980s probably were a lingering effect of the strong El Niño event that occurred in 1982-83. Intense winter storms caused an abnormally large number of females to lose their dependent pups, thus apparently resetting the annual birthing pattern for several more years. The same effect seems to have occurred in 1998. Even so, there is no indication of reproductive failure associated with the onset of the recent population decline.

ASSESSMENT OF CURRENT POPULATION STATUS

After at least 10 years of uninterrupted population growth, the California sea otter now appears to be in modest decline. There are three possible demographic explanations for the decline. One is that some of the otters have moved elsewhere. It is highly unlikely that the missing animals have moved to some other coastal area because the entire region is under almost constant surveillance by boaters and coastal observers. The distribution of otters may also have shifted offshore, thus decreasing the probability of an individual being observed during a survey. There is no evidence that distributional shifts of this nature occur in sea otters, nor have we noted any such change in the location of individuals during the surveys. We thus regard this possibility as unlikely, but worthy of further investigation. Another possibility is that the population has declined because of depressed reproduction. Again, the evidence both from past studies and the currently available data does not support this explanation. A third possibility is increased mortality. We regard this latter possibility as the most likely cause of the decline.

Mortality is difficult to study in wildlife populations. The only record of mortality patterns available for the California sea otter in recent years is the number and character of beached carcasses. At best, these materials provide a crude indicator of overall mortality because an unknown proportion of dead otters is recovered and it is uncertain that individuals found dead on the beach are representative of deaths in the population as a whole. While the number of carcasses recovered has increased in rough accordance with the population decline, there are no evident changes in cause of death in the freshly stranded animals. Since infectious disease has been shown to be the cause of death in almost half of the beached carcasses, any significant change in the incidence of this mortality source would be expected to appear as an increase in the proportion of diseased individuals among those that are necropsied. This pattern is not seen (Fig. 4) and thus we think it unlikely that an increase in infectious disease is responsible for the population decline. There are other possibilities, one of which is increased incidental take in fishing gear. In view of the recent growth of coastal pot fisheries, reports of otters being caught and killed in these pots, and high likelihood that incidental losses in fishing gear were responsible for an earlier population decline, the possibility of growing entanglement losses warrants further attention. Recent estimates of sharply increased sea otter losses in gill and trammel nets adds to this concern and the complexity of the issue.

Despite reasonably strong evidence for a recent population decline, the range of the California sea otter has continued to expand southward, thus resulting in about 100 individuals moving into the “no otter zone” south of Point Conception during late winter/spring of 1998. This situation raises the question of how compliance with Public Law 99-625 would affect the welfare of the California sea otter population. The easiest scenario to evaluate is that of removing these animals without placing them elsewhere. Inasmuch as the California sea otter population is in decline, such removals without replacement most likely would be additive to current losses, thus causing the population to decline even more rapidly. The potential consequences of removal with replacement are less certain, although several predictions are possible either from first principles of ecology or past experience. Relocations of these animals, either within the existing range north of Point Conception or outside the existing range, can be expected to cause the deaths of some of the relocated individuals. In addition, many of the relocated individuals almost certainly would return to the locations from which they were captured. There is also concern over how the relocated animals would interact with resident otters. The fact that these animals dispersed from the existing range makes it likely that their forced return would compromise the system in some manner, the two most likely mechanisms being via resource competition with the residents and disruption of the residents’ social systems. Both processes would likely be detrimental to the residents. On the other hand, it is difficult to see how the residents might benefit from the intruders. In sum, regardless of exactly what is done with animals taken from the “no otter zone,” removal of these animals would be detrimental to the California sea otter population. This issue may now seem moot because only a single sea otter was sighted south of Pt. Conception during the most recent (October) survey of the area. However, this is likely a seasonal pattern, and large numbers of otters should be expected to return the area south of Pt. Conception in late winter or spring of 1999.

There is little doubt that the California sea otter population would be best served by elimination of the "no-otter zone." This now appears essential for natural range expansion, and thus recovery, of the California sea otter. Disturbances to animals in this area will be detrimental to the population.

INFORMATION NEEDS

Conservation and management issues surrounding the California sea otter are complex and thus there are diverse needs for further information. Three specific problems require special attention. One is the issue of incidental losses of sea otters to fisheries. Further work is needed to assess whether such losses are of sufficient magnitude to be causing the population to decline. A second need is for basic information on sea otter demography and behavior. We have argued that reproductive failure is not responsible for the recent population decline, but in fact there have been virtually no data gathered since 1995 to assess that possibility. The same can be said of redistribution and mortality. A focused research program based on tagging and radio telemetry is needed to answer these questions. In view of the fact that a study of this kind was conducted during a time when the California sea otter population was growing (Siniff and Ralls 1989), similar information from the present would provide an illuminating contrast that would help clarify the reason for the current decline. A third need is to better understand the role of infectious disease in the population biology of California sea otters. Continued monitoring and detailed necropsies of fresh carcasses should receive high priority. The present policy of conducting detailed necropsies on every fourth otter is limiting our understanding of the decline but greatly reducing the power of the data to detect change. Although a reduced effort was justifiable while the population was still growing, it is no longer so now that the population is in decline. Further information on the history of disease and the ecology of the various parasites and disease organisms would also be of great value to understanding the status and trends of the California sea otter population.

Appendix E: Comments Submitted on Draft Revised Southern Sea Otter Recovery Plan Dated January 2000

In January 2000, we released the Draft Revised Recovery Plan for the Southern Sea Otter for public comment. During the comment period, we received 91 letters from Federal, State, and local agencies, nongovernmental organizations, business associations, and other members of the public. All letters of comment on the draft recovery plan are kept on file in the Ventura Fish and Wildlife Office, 2493 Portola Rd., Suite B, Ventura, California 93003. The following is a breakdown of the numbers of letters received from various affiliations:

Federal agencies–6
State agencies–3
local governments–1
nonprofit environmental/conservation organizations–9
commercial fishing and aquaculture associations–5
recreational groups–1
academia/professional–1
individual citizens–65

Many comments re-occurred in letters. The vast majority of responses came from individual citizens and expressed concern for the southern sea otter and support for research and recovery actions. Several comments either provided new or additional information for inclusion in the recovery plan or were editorial in nature. Those comments were incorporated into the final revised plan. Comments that were not incorporated into the recovery plan are summarized below along with our response.

Summary of Comments and our Responses

Comment 1. One commenter stated that the recovery plan should explain why the population should be viewed as endangered at a level where both the numbers and range would be greater than when the population was listed as threatened in 1977.

Response. This recovery plan incorporates current conservation biology principles. The initial listing and status classification did not have the benefit of such current thinking. Rather, the original classification of threatened was based on the presumed risk of extinction.

Comment 2. One commenter stated that it would be useful to note in the recovery plan revision why the type of population viability analysis described on page 25 of the draft revision was not or could not be done in the process of formulating the original recovery plan.

Response. Inclusion of such a discussion does not serve the purposes of the plan; *i.e.*, to identify the recovery criteria and tasks. Such an analysis was not completed in the 1982 recovery plan because that plan did not address the conditions under which the southern sea otter should be considered for reclassification as endangered.

Comment 3. One commenter stated that the table included as Appendix A does not, but should, provide estimates of the amount of range occupied by sea otters from 1982 to the present.

Response. The initial recovery plan provided estimates of the amount of range occupied by the sea otter as well as the population count. Later, as the sea otter population began to grow again subsequent to the restriction of gill and trammel nets, it became more difficult to identify the actual range occupied by the sea otters, and furthermore, it was difficult to find consensus amongst biologists as to what actually constituted the limits of the occupied range. Some suggested that range should be defined as all habitat in which sea otters occurred, including extra-limital sightings; others suggested it should be defined as the range in which females with pups were found. Pronounced seasonal movements of male otter groups further clouded this issue. Therefore, we decided that, to avoid confusion, it was best to present the table with only the population count data.

Comment 4. One commenter stated that pup counts are not important and recommended that recovery and delisting decisions use data for independent otters only. The commenter further stated that if pups are to be included, we need to provide a clearer rationale for using the spring counts.

Response. We and the Recovery Team believe that pup counts are important, and the recovery criteria will be based on spring counts. Pup counts provide an index of annual productivity, which is important when assessing the status of the population and evaluating other indicators of population health. The recovery plan does explain that spring counts have been established as the standard for assessing trend and population size because the conditions are more favorable for counting sea otters (*i.e.*, bull kelp is not present). During the fall counts, bull kelp is present and makes counting sea otters more difficult.

Comment 5. One commenter suggested including other human activities besides oil activities and commercial fishing, such as kelp harvest, use of personal water craft, other recreational uses (*e.g.*, kayaking, diving), impacts of contaminants, etc.

Response. Recovery plans identify those threats known to cause the species to be at risk of extinction including those identified at the time the species was listed and any additional threats subsequently identified. These other suggested activities were not included in the recovery tasks because they are not known to be threats contributing to the species' risk of extinction. If at any time in the future new threats are identified, the recovery plan can be updated to include these threats and management actions necessary to secure the protection and conservation of the sea otter.

Comment 6. One commenter recommended that we use a different factor for calculating the size at which the southern sea otter population should be considered endangered; *i.e.*, the threshold should be 1,550, not 1,850.

Response. The best available information regarding the threshold for endangered status for the southern sea otter was identified as that presented in the paper by Ralls *et al.*

(1983). In this paper, the authors considered the life history characteristics of the sea otter and determined that the correction factor of 27 percent is appropriate for the southern sea otters. Therefore, we did not change the threshold value.

Comment 7. One commenter asserted that the statement that sea otter populations in various geographic locations exhibit a wide range of growth rates and are thought to differ in life history parameters contradicts the Alaska sea otter stock assessments, which assumes a single high growth rate when assessing the stocks in Alaska.

Response. The statement within the draft revised recovery plan was a general statement comparing all sea otter populations and is supported by available literature. In Alaska, the sea otter population growth rate has ranged between 17 and 21 percent, while in California the southern sea otter population growth rate has ranged between 5 and 7 percent.

Comment 8. One commenter was concerned that the implication of recommending a 5-year study is that until the data from such a study are acquired, no management action will be taken. Given the continued decline of the population, the precautionary principle urges action that benefits the population in the absence of knowledge.

Response. We do not intend that no action will be taken until studies are completed and data analyzed. The responsible agency will take action using the best available information, subject to the availability of funds.

Comment 9. One commenter objected to what was believed to be the numerical objective for recovery as 8,400 sea otters along the California coast. It was further stated that there was no explanation for that number.

Response. This recovery plan, as well as the 1982 original plan and all subsequent drafts, recognizes our responsibility for managing sea otters not only under the Endangered Species Act, but also the Marine Mammal Protection Act. The recovery plan clearly recognizes that once the recovery objectives are achieved pursuant to the Endangered Species Act, we still have obligations under the Marine Mammal Protection Act. Those obligations are to restore the sea otter population to its optimum sustainable population level. Past efforts at determining marine mammal optimum sustainable population levels have identified the lower bound to be roughly 50-60 percent of the habitat's current carrying capacity. For the southern sea otter this lower bound is approximately 8,400 animals for the entire California coast, based on estimated historic population levels. A marine mammal population below its optimum sustainable population level is considered depleted. A conservation plan will need to be developed detailing methods for restoring the population to its optimum level.

Comment 10. One commenter believed that the recovery plan should reference the "seminal works" on sea otters.

Response. The original recovery plan recognizes much of the early literature on sea otters. The original plan is still available for anyone interested in obtaining these references. In developing this plan, we and the Recovery Team chose predominantly to cite current peer-reviewed literature. This recovery plan does direct readers to contact us or other agencies for additional information, if desired.

Comment 11. One commenter recommended that the recovery plan should provide alternatives and an evaluation of the risks, and that there should be public hearings.

Response. Recovery plans are developed for species at risk of extinction; the plans should identify the threats to a species, recommend tasks by which the threats can be removed, and state the criteria by which the species is no longer considered to be at risk of extinction and in need of protective measures under the Endangered Species Act. The plan is a "road map" to recovery. There may be other means to get to recovery, other means by which the threats are eliminated. The recovery plan does not preclude other efforts to eliminate the risks; those could be pursued. Under most circumstances, only as specific tasks are implemented is the NEPA process invoked. During this process, alternatives are identified and evaluated, public meetings are held, and comments are evaluated before actions are implemented

Comment 12. One commenter recommended that we revise the five criteria that are evaluated in any proposed rule or final rule to add or remove a species from the Federal list of threatened or endangered species pursuant to the Endangered Species Act.

Response. Section 4(a)(1) of the Act and regulations (50 CFR part 424) issued to implement the listing provisions of the Act identify the factors that must be evaluated to determine the classification of a species. The five criteria that are analyzed in all Federal rulemakings are: 1) The Present or Threatened Destruction, Modification, or Curtailment of Its Habitat or Range; 2) Overutilization for Commercial, Recreational, Scientific, or Educational Purposes; 3) Disease or Predation; 4) The Inadequacy of Existing Regulatory mechanisms; and 5) Other Natural or Manmade Factors Affecting its Continued Existence. These factors cover all possible threats and we do not believe they should be changed.

Comment 13. One commenter recommended that we or the U.S. Geological Survey should write and publish a comprehensive summary of information obtained since 1990.

Response. Although a comprehensive summary of information is not available and resources are not available for such an effort at this time, new information is published. Information is continually being updated and reviewed through a variety of reference sources; however, there is inadequate funding to compile all information into a single document at this time.

Comment 14. One commenter believed that the recovery plan greatly overstates the threat and effects of oil spills and stated that there is no discussion of oil spills that have affected California sea otters.

Response. There have been several events along the California coast that could easily have resulted in a large oil spill within the range of the southern sea otter. For example, in 1982, the Sealift Pacific lost steerage and nearly grounded along the Big Sur Coast. The vessel was able to stop its movement toward the shore by dragging its anchor. In 1992, an onshore pipeline broke and oil spilled into Avila Bay. Four oiled sea otters were removed from that area. We acknowledge that to date there has been no large oil spill in the range of the southern sea otter that has caused a high level of mortality. However, the *Exxon Valdez* oil spill event clearly demonstrates that a large-scale oil spill can occur, and that if one occurs within the range of sea otters, it will be capable of causing substantial mortality of sea otters and habitat degradation. We and many other agencies and organizations are concerned about the threat of oil spills and their effects on the California coastal environment. Because of the threat of oil spills, the U.S. Coast Guard and the Monterey Bay National Marine Sanctuary established an interagency team to develop a proposal to reduce oil spill risk from vessel traffic. A plan was developed and subsequently approved by the International Maritime Organization that manages international vessel routing.

Comment 15. One commenter recommended that we develop a sea otter containment program in collaboration with fishermen, who would provide matching funds to ensure ongoing capture capability.

Response. This comment is best addressed relative to our current effort toward developing a supplemental environmental impact statement on the translocation program. Because of the current status of the southern sea otter population and the changed circumstances surrounding the original translocation program, we are currently developing a supplemental environmental impact statement on the translocation program. As part of this effort, we have solicited public input through the scoping process and will be evaluating public comments and program alternatives. This recommendation, if it was submitted during the scoping process, can be evaluated for consideration.

Comment 16. One commenter recommended that habitat protection should have a high priority (regardless of listing status), and that an assessment of negative impacts (loss of kelp beds and shellfish larvae) on the coastal habitat from projects such as municipal sewer outfalls, silt, and pesticides in runoff and water intake and discharge from power plants be done. Areas or projects where negative impacts are occurring should be corrected or mitigated.

Response. The recovery plan does identify habitat issues known, or suspected, to threaten the southern sea otter (*e.g.*, contamination and disease). The recovery plan identifies the need to determine the causes of the problems and identify management actions that eliminate or reduce the threat. As new information becomes available identifying causes of habitat degradation, research and management efforts can be recommended to restore the coastal ecosystem.

Comment 17. A few commenters questioned how cessation of the "otter-free-management zone" would promote recovery of the southern sea otter.

Response. The translocation of southern sea otters to San Nicolas Island has been less successful than originally hoped for as a means of establishing a second, self-sustaining population of southern sea otters. Furthermore, the value of the colony, as originally envisioned, was to repopulate the mainland population if decimated by an oil spill, or some other event, by translocating small numbers of animals from San Nicolas Island. Experience has demonstrated that this goal may not be achievable given the tendency of translocated sea otters to disperse. The mainland population is still threatened because of its small population size and limited distribution. Recovery can best be achieved by having a larger number of southern sea otters distributed over a larger area. Since 1998, southern sea otters from the central coast seasonally have moved south of Point Conception into the management (otter-free) zone. Containment of these animals (*i.e.*, their capture and relocation back into the mainland population), in perpetuity, does not enhance recovery and, if moving large numbers of animals, is likely to adversely affect the mainland population, by disrupting social dynamics, increasing competition, etc. The natural movement of sea otters into a larger area would be better for the sea otter.

Comment 18. One commenter asked how, if the minimal viable population for sea otter is approximately 1,850 animals, we could have published a nonessential designation for moving 150 sea otters to San Nicolas Island when the fall survey for 1987 was 1,367 animals (that is, 483 animals fewer than 1,850 animals).

Response. It is important to note that the original target of 150 animals was the total number of animals that could be moved to San Nicolas Island over the term of the permit. This total number of animals was not permitted to be moved in a single year. However, the number of animals in the population at the time of the translocation was below the minimal viable population figure. This figure (1,850 or fewer) has been provided as an index as to when the southern sea otter population status should be considered endangered pursuant to the Act. The determination of the listing status of a species pursuant to the Act is different than the determination whether an experimental population under section 4(d) of the Act is essential or nonessential. The essential/nonessential determination has relevance only with respect to section 7 of the Act. If we had believed at the time of initiating the translocation that all 150 sea otters would be lost shortly after the translocation, the translocation would not likely have proceeded at that time or as designed.

Comment 19. One commenter recommended that we should study risks to sea otters south of Point Conception, impacts to other resources such as abalone, impacts to sea otters from offshore oil, sewage, nuclear power plant operations, etc., and economic impacts and potential impacts on other life-forms by foraging sea otters.

Response. We are currently undertaking a supplemental environmental impact statement on the translocation program. This effort will re-evaluate the threats and impacts addressed in the original environmental impact statement for the translocation of sea otters. This document should satisfy the recommendations stated above. There is no environmental impact process for evaluating the threats to southern sea otters in their current range. However, the recovery plan does identify a need for the further evaluation of threats, the determination of their sources, and the development of reasonable and prudent measures to minimize them.

Comment 20. Several commenters recommended the improvement of survey methods.

Response. We recognize that the current survey methodology does not count every sea otter. The survey is designed and intended to provide a standardized method for counting southern sea otters, and thus to provide an index for assessing population trends. We do believe that it is important to evaluate periodically whether the best methodology is being used. However, we believe that changing survey protocol at this time would confound efforts to assess and to understand the status of the southern sea otter population because data collected under a different protocol would not be comparable with the data already collected for previous years.

Comment 21. One commenter stated that the recovery objective of 8,400 sea otters for the entire California coast is excessive and requested that the number be changed to the lower number of 5,400 as in the 1991 draft plan.

Response. The figure 8,400 is the estimated recovery goal for achieving the optimum sustainable population level under the Marine Mammal Protection Act. The Marine Mammal Protection Act states that the goal for managing marine mammals should be to obtain an optimum sustainable population keeping in mind the carrying capacity of the habitat. An optimum sustainable population for the southern sea otter is likely a level equal to 50 to 80 percent of its current carrying capacity. The lower bound of the optimum sustainable population is approximately 8,400 animals for the entire California coast, based on estimated historic population levels.

Comment 22. One commenter suggested that the recovery plan should include language to allow the concept of zonal management in order to protect "the balance of our marine resources."

Response. It is important to note that recovery plans do not allow or authorize any activity. A recovery plan is a guidance document that identifies recovery criteria and our recommended actions for restoring the species to a status that it no longer needs the protective provisions of the Endangered Species Act. Regarding zonal management, the Southern Sea Otter Recovery Team believes that the primary action for promoting the recovery of the southern sea otter at this time should be the cessation of the management zone, and that without such a change in management, the likelihood of recovery is significantly lessened. We are taking this recommendation and other information under consideration and evaluating several alternative courses of action, including the continuation of zonal management, through the National Environmental Policy Act process.

Comment 23. Several commenters recommended that an "implementation team" be created, so that after the recovery plan is approved, recovery tasks can be set in motion.

Response. Although the formulation of an implementation team is not necessary to activate recovery actions, such a team can be useful as an advisory body regarding recovery efforts and can effectively serve to facilitate collaborative efforts. We will consider this recommendation and how it can best be implemented.

Comment 24. Numerous commenters stated the importance of declaring the San Nicolas

Island translocation a failure and ending zonal management. Reasons noted were: 1) risk to sea otters associated with capture and relocation; 2) undue stress placed on sea otters living in the area to which sea otters would be translocated; 3) exacerbating food limitations and habitat degradation; and 4) disrupting existing social structure.

Response. We are currently developing a supplemental environmental impact statement to reevaluate the southern sea otter translocation plan as described in the final Environmental Impact Statement for Translocation of Southern Sea Otters, Appendix B, May 1987. Through this process, we will consider the current program, modifications to the program, and termination of the program. The supplemental environmental impact statement will update information, assess the impacts of proposed alternatives, provide for public participation, and ultimately identify an alternative that will reduce the southern sea otter's vulnerability to extinction.

In response to comments received on the January 2000 draft revised plan, we asked the Recovery Team to complete a trend analysis to determine the population size that would be robust enough for us to detect trends in abundance reliably prior to the population declining to endangered status. In April 2002, we submitted this analysis for peer review by Alan Hastings (UC Davis), Marcel Holyoak (UC Davis), John R. Sauer (USGS-Patuxent Wildlife Research Center), and Dan Goodman (Montana State University). Their comments are summarized below:

Comment 1. Several reviewers questioned whether the use of a 5 percent rate of decline was appropriate considering that the rate of decline observed in the Alaska population was 16 percent or more.

Response. If one assumed a 16 percent rate of decline, with the same trial scenario as used originally (*e.g.*, CV = 0.1, alpha = 0.1, etc.), it would take 5 years to get a high likelihood of detecting a decline, during which time the population would drop by 58 percent. Therefore, the buffer above 1,850 would be 2,590 animals for a threshold of 4,440 animals (1,850 + 2,590). The Recovery Team finds using the higher rate of decline unreasonable for the California population because it has never been observed in California, and prefers to use the maximum rate of decline observed in the population since monitoring was initiated.

Comment 2. Several reviewers recommended conducting simulation trials to look at the robustness of the listing criteria (including trend analysis) and the 3-year running average index.

Response. Although this exercise would be valuable, it would take a programmer/analyst several months at a minimum to complete the work, at a cost of about $15,000. The Recovery Team recommended, and we agreed, that we should not delay completing the final revised recovery plan in order to complete this analysis. Rather, we should make final the current version of the recovery plan and then undertake the analysis and incorporate the results as part of the next status review in 5 years.

Comment 3. Several reviewers noted that using the 3-year running average is conservative when considering delisting, but it is not conservative when considering uplisting (*i.e.*, going from threatened to endangered).

Response. Most of the Recovery Team preferred to trigger uplisting to endangered if the population falls below 1,850 in a single year. However, the Fish and Wildlife Service has determined that it is appropriate to use the 3-year running average when considering uplisting. Because population counts have fluctuated from one year to the next, we believe it is prudent to use the 3-year running average to characterize population size during a given year. For example, if we used a single year count as the criterion to initiate reclassification to endangered when the population count is at or below 1,850, then during the course of developing and proposing a reclassification, if a subsequent count were above 1,850, we would have to terminate that proposal effort (thus making inefficient use of limited staff time). Using the 3-year running average is both consistent with how we assess population size and should provide assurance that the population is adequately characterized if we propose uplisting or delisting. (See also the response to Comment 2 above.)

Comment 4. Two reviewers commented that changes between years could be extreme and that linear trends may be less of a worry than nonlinear trends.

Response. The Recovery Team did not support this consideration, as increases and decreases in abundance of the California sea otter population since the 1970s have been approximately linear, with decreases in the late 1970s and early 1980s (likely due to density-independent mortality related to fishery interactions), increases from the mid-1980s to the mid-1990s, and then decreases from the mid-1990s to 2000.

Comment 5. One reviewer recommended that we verify that the coefficient of variation (cv) of the index counts are relatively constant and approximately 0.1.

Response. The cv (of 0.1) was estimated by deviations from the best fit to trends in the population count data. This method of estimating the cv is a very reasonable one; the only other way would be to replicate counts in a given year, which would be extremely expensive in terms of time and money.

Comment 6. One reviewer questioned why we did not use Lande's 5,000 figure when determining the criteria for when the southern sea otter should be considered endangered.

Response. Basically, Lande's calculation was for a time scale on the order of thousands of years. The Recovery Team thought that a time scale of decades to a century was more appropriate for management purposes; hence the 500 number was used

Comment 7. One reviewer raised a point that the 10 years required to detect a trend of less than 5 percent per year does not allow time for us to react and attempt mitigation.

Response. This point is valid. A simulation analysis would allow an evaluation of the probability of detecting a given decline in a given number of years. (See the response to Comment 2, above.) Furthermore, the simulation analysis needs to take into account the time it takes to propose and make final a reclassification ruling. The results of the analysis should be incorporated as part of the next status review in 5 years.