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Assessing the Threat of Oil Spills to Southern Sea Otters

Michael L. Bonnell, R. Glenn Ford, and Allan J. Brody

The California population of sea otters was listed as threatened under the Endangered Species Act in 1977 due to its small size, isolated and limited geographic range, and vulnerability to oil spills (Federal Register 42:2965-2968). Today the population, although increasing slowly, is still small, and its range has not appreciably increased. Consequently, its vulnerability to oil spills remains high.

The threat of oil spills to the California population has been underscored in recent years by three vessel accidents with release of oil or bunker fuel that had the potential of contacting sea otters. These were a leaking barge towed south from San Francisco (the Apex Houston, February 1986), the explosion of a tanker off San Francisco (the T/V Puerto Rican, October 1984), and a barge taking on water off Cape San Martin (the Spartan 120, May 1983). Additionally, there have been two near-groundings of deep-draft vessels along the central California coast (the Sealift Pacific in April 1984 and the T/V Austin in April 1980); both groundings were narrowly averted after the vessels drifted to within a few kilometers of the sea otter range.

The Exxon Valdez oil spill clearly demonstrated the sensitivity of sea otters to oiling. Approximately 11,000,000 gallons (42,000,000 liters) of crude oil were released into Prince William Sound when the vessel grounded in March 1989; subsequent winds carried oil southwestward to contaminate waters off the Kenai and Alaska peninsulas and Kodiak Island. Best estimates of mortality range from 2,650 (Garrott et al. 1993) to 3,905 sea otters (DeGange et al. 1994).

The California population of sea otters has, thus far, escaped significant impact by oil spills. However, most researchers (including the authors) believe that a spill is inevitable and therefore planning a response is essential. Based on spills that have occurred, the greatest threat to sea otters is from tanker and barge accidents. Spills at oil production platforms and pipelines are far less likely to have a major impact on sea otters because of the location of platforms in relation to the sea otter range and the typical pattern of winds and currents along the coast.

The magnitude of the threat can only be estimated as the probability of future events based on the occurrence of past events. To extrapolate from historical data, the assumption must be made that improvements in tanker safety, navigation, and construction are inconsequential. This assumption is probably suspect; clearly such improvements should have a beneficial effect and be encouraged. However, safety improvements may not be enough; given the sophisticated tracking/warning systems in place, the Exxon Valdez spill in Prince William Sound should never have occurred.

Historical data can be used to credibly estimate the number and size of spills that might occur over a given time period. Although small spills occur much more often than large ones, most are at marine terminals during transfer of oil or refined product. Consequently, small spills are less likely to reach sea otters and, when they do, result in limited mortality. In contrast, most spills from vessels at sea are large (many thousands of gallons).

While the probability of such accidents is low, large spills along the open coast can have large impacts. Substantial threat to sea otters exists from all vessels in transit past the central California coast due to quantities of bunker fuel. Tankers, which account for about 28% of all vessel traffic to or from ports in San Francisco Bay, pose an exceptional threat; relative to other vessels, tanker spills may be five time as large (U.S. Coast Guard 1996).

Learning from history

From analysis of tanker oil spills in U.S. waters between 1974 and 1989, it has been estimated that spills of 1,000 to 100,000 barrels (bbls; 42 gal/bbl) have an occurrence rate of 0.19 per billion bbls transported, and spills greater than 100,000 barrels have an occurrence rate of 0.13 per billion bbls (Minerals Management Service 1994; see Anderson and LaBelle 1990). A reasonable approximation of the quantity of oil and petroleum product transported per year can be obtained from commodity flow statistics for waterborne commerce of the United States, developed by the U. S. Army Corps of Engineers, and import-export statistics compiled by the Bureau of the Census. Using these numbers, the total quantity of oil and petroleum product transported into San Francisco Bay or past the sea otter range in 1989 was 450 million bbls (U. S. Coast Guard 1996). Assuming that the same volume is transported each year, the projected quantity over 10 years is 4.5 billion bbls and, over 30 years, 13.5 billion bbls.

Based on the history of oil spills in U. S. waters and the volume of oil and petroleum product transported, we might expect at least one oil spill of 1,000 bbl or greater in the next 10 year period, and three in the next 30 year period. These are minimum expectations‹because each oil spill is an independent event, the occurrence of one oil spill does not diminish the likelihood of subsequent spills. It should be recognized that these spills could theoretically occur anywhere along the tanker route. However, most spills off the Pacific coast in the last 30 years have occurred close to land and particularly as tankers make their approach to port (U. S. Coast Guard 1996).

Modeling contact of sea otters by oil spills

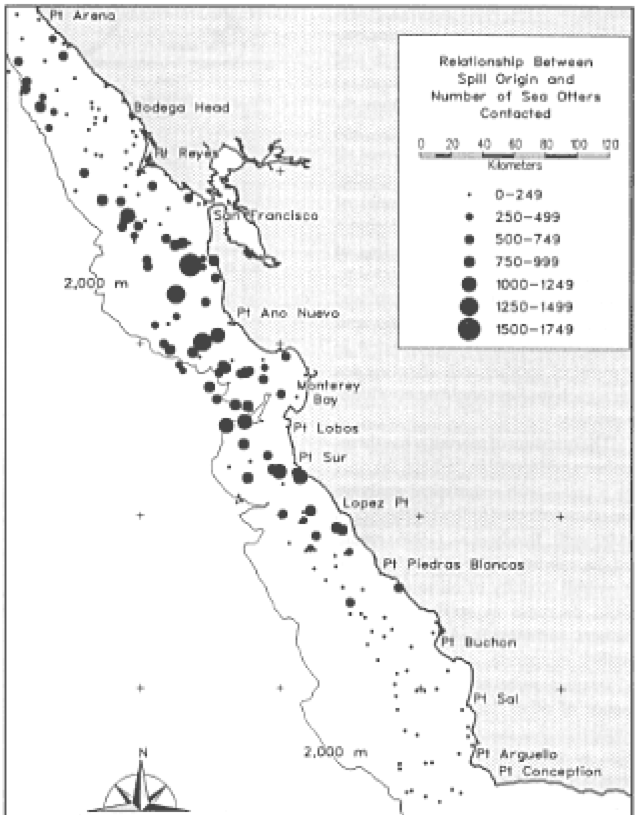
Although we cannot be sure of when or where oil spills will occur, we can use statistical models to examine their potential impact on the sea otter population. This can be done by conducting many computer simulations of oil spill events, with random selection of spill origin, size, and date, followed by examination of the results.

In an analysis of potential impacts of oil spills on the southern sea otter population for the U. S. Fish and Wildlife Service (FWS), Ford and Bonnell (1995) simulated the movement and spread of oil spills using a database of actual winds recorded from the National Oceanic and Atmospheric Administration meteorological buoys and seasonally averaged surface current vectors from a curvilinear grid provided by the Minerals Management Service. Spills of 31,250 to 1,000,000 bbls were simulated, where each spill was represented as a cluster of independently moving points (Lagrangian Elements, or LEs), each representing a portion of the entire spill volume. Spreading was simulated using a random diffusive factor based on the areal extent of oil slicks over time documented in past spills (Ford and Casey 1985). For each size category of oil spill (31,250, 62,500, 125,000, 250,000, 500,000, and 1,000,000 bbls), 200 model runs were conducted, each consisting of 100 LEs. The date (for selection of a time-series of winds) and spill origin were assigned using a random number generator. The position of sea otters was defined using a digital distribution from 1992 data provided by the FWS. The movement of each LE was tracked in 2-hour time steps; contact was scored if an LE passed within 5 km of sea otters. This radius was chosen as an approximation of the areal extent of a 2,500 bbls spill (Ford and Casey 1985). The model was relatively insensitive to this parameter‹a 100% increase in size increased number of contacts by only 3.6%.

The number of sea otters contacted by simulated spills of 250,000 bbls (the size of the Exxon Valdez spill) at randomly selected locations within 25 nautical miles (nmi; about 46 km) suggests that spills of this size result in greatest contact with sea otters when occurring from the Gulf of the Farallones off San

Francisco to about Lopez Point (see Figure 1). This is not surprising given the typical movement of drifting oil in a southeasterly direction and the distribution of sea otters. What is surprising is that spills farther from shore might produce a greater impact than groundings.

Figure 1. Spill origins scaled according to number of sea otters contacted for 200 simulations of 250,000 bbl spill at randomly selected sites within 25 nml of land.



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To examine this pattern, Ford and Bonnell (1995) conducted simulations of spills evenly spaced along lines orthogonal to shore and extending to a distance of 110 km (about 60 nmi). The results suggested that the greatest number of contacts with sea otters in a 21-day period would typically occur from spills north of the present range and relatively far from shore. The consequences of spills in waters off San Francisco were greatest 60-70 nmi offshore because oil would drift into the center of the range along the Big Sur coast. Off Point Año Nuevo, the number of sea otters contacted remained high for oil spills within about 30 nmi from shore. On other lines farther to the south, spills within 10-20 nmi produced the most contacts. These results are easily understandable considering that oil from spills close to land must be deposited in areas of high density to contact many sea otters. Large spills offshore, especially to the north, can contact a more extensive portion of the range as they drift southeastward with winds and currents.

Not unexpectedly, the number of contacts increased with the size of the simulated spill. However, the relationship of sea otter contacts and spill size proved to be nonlinear. At the 95th or even the 90th percentile (i.e., only 5-10% of model runs resulted in a greater number of contacts), roughly two to three times as many sea otters were contacted by a 1,000,000 bbl spill as by a 31,250 bbl spill despite a 32-fold increase in spill volume. For a 31,250 bbl spill, the 95th and 90th percentile simulation resulted in 552 and 456 sea otters contacts, respectively. The worst case of 200 model runs for a spill of 31,250 bbls resulted in 1,119 sea otter contacts, representing nearly one-half of the existing population. The lesson is that even a relatively small spill of 31,250 bbls can cause a major and perhaps irrecoverable impact on the sea otter population.

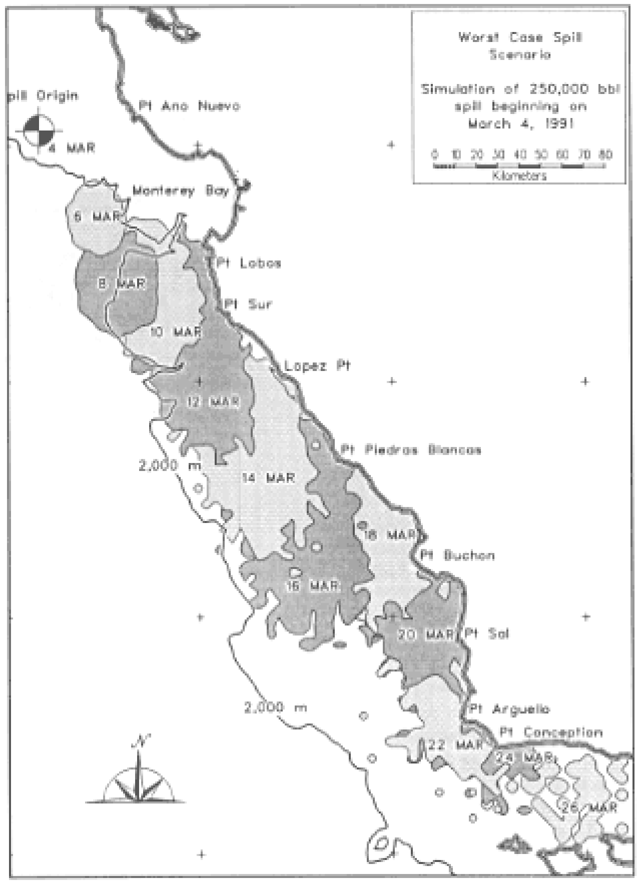
Mortality of sea otters

Given that a substantial number of sea otters are contacted, what might be the mortality? This is a difficult question to answer because mortality of each individual sea otter is determined by the degree of oiling and this, in turn, is affected by the amount of oil in sea otter habitat and how long it remains. Sea otters may survive initial contact but succumb in following days due to repeated exposure to oil. Working in favor of sea otters is weathering of oil as it drifts, and the opportunity provided for clean-up and use of dispersants.

Many factors influence direct mortality of sea otters once they are contacted by spilled oil. Oil is toxic to sea otters in at least three distinct ways: lung damage from inhaled volatile components, gastrointestinal damage and perhaps systemic toxic effects from oil ingested while grooming, and hypothermia following oiling of pelage. Sea otters dying from oiling may evince all three. However, the basic data needed to construct a mechanistic model of individual sea otter mortality during a spill, which would allow modeling of spill impacts "from the bottom up," simply do not exist. One of the missed opportunities of the Exxon Valdez spill was that such data were not collected. In the event of another spill affecting sea otters, such studies should receive highest priority.

The question of mortality has therefore been addressed in perhaps the only way it can‹with a statistical analysis. Using data collected following the Exxon Valdez spill, Brody et al. (1996) examined the validity of the assumption that the overall toxicity of oil to sea otters should decrease as spilled oil ages, weathers, and spreads. As oil weathers, volatiles evaporate, caustics degrade, and the oil itself becomes diluted. In the absence of other data, they tested the assumption that distance from the spill origin to point of contact with individual sea otters might serve as a reasonable surrogate for detailed data on the state of oil and the degree of exposure‹the greater the distance that oil drifted, the less likely that oiled sea otters would die. For nearly 300 sea otters captured in rescue efforts following the spill, a survival rate was calculated as a function of the distance from the spill origin to capture sites along the trajectory of oil. The survival rate function provided a good fit with the data, indicating that no sea otters would survive at the spill origin, about 50% would survive at a distance of 150 km, and survival of sea otters at greater distances would asymptotically approach 100%.

Figure 2. Time-course of movement and spread of oil from the 100th ranking simulation of a 250,000 bbl spill. This simulation resulted in the greatest number of sea otters contacted out of 200 simulations at randomly selected sites within 25 nml from land.



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This relationship presumed that survival of captured oiled sea otters is representative of a population of oiled animals observed but not removed from their contaminated habitat. It seems likely that many sea otters left to their fate would additionally have become oiled over time until they ultimately died of toxic effects and hypothermia. Thus, estimates of mortality derived from the relationship should be viewed as minimum values. It is also important to remember that these estimates are of mortality from direct contact with oil; should oil remain and degrade sea otter habitat, additional and long-lasting impacts on the population may result.

Table 1. Number of sea otters contacted an estimated mortality resulting for 100th percentile worst case scenario of a 250,000 bbl oil spill.

Day	Number Contacted	Mortality	Cumulative Contacted	Cumulative Mortality
0	0	0	0	0
1	0	0	0	0
2	0	0	0	0

Detailed scenarios were produced for the 100th and the 90th percentile contacts of a 250,000 bbl spill (about the size of the Exxon Valdez) on the California population. In each of these simulations, 2,500 LEs were tracked to determine distance of drift prior to contact with sea otters. The 100th percentile spill contacted 1,820 sea otters of which 777 ultimately would die using the relationship of Brody et al. (1996; see Figure 2 and Table 1).

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

Unfolding of the spill episode is illustrated by the following time-course. The simulated spill occurred 36 km (19.5 nmi) west of Point Año Nuevo with oil driven by real-time winds recorded from March 4 through 25, 1991. Over a three-week period, northwest winds were interrupted repeatedly by the passage of storms. South and southwest winds associated with low-pressure cells slowed southward movement of the slick and allowed it to move closer to shore. Contact with sea otter habitat first occurred six days following the release when oil beached near Point Lobos. Oil continued to enter sea otter habitat over the next three days under variable west and northwest winds to about 20 knots and resulted in heavy contamination of near-shore 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 knots, sparing parts of the sea otter range between Point Sur and Point Lopez. On day 12, south, southwest, and west winds of 20 knots or more again pushed oil toward shore, initially resulting in heavy oiling of sea otter habitat near Point Piedras Blancas. 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 knots 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. In this simulation, mortality was about 37% of the spring 1992 population; in heavily contaminated portions of the coast from Point Lobos to Point Sur, the local population suffered mortality approaching 55%.

Using the 90th percentile worst case resulted in contact of 881 sea otters and, using the relationship of Brody et al. (1996), resulting in mortality of 456 animals. This spill originated about 36 km (19.5 nmi) northwest of Point Año Nuevo. The simulated spill was driven by real-time winds of August 11 through 31, 1990. Initial contact with sea otters in the vicinity of Point Año Nuevo occurred on the day after release. Over the next two days, oil moved southward along the shore under northwest winds of 15-20 knots. Four to five days following the simulated spill, oil entered Monterey Bay resulting in heavy contamination of near-shore waters in the southern part of the Bay and then moved southward along the Big Sur coast to about Point Lobos. Five to six days after release, oil drifted south in a compact 10 km wide slick contacting sea otters along the Monterey Peninsula to beyond Point Sur. Oil 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 near Point Piedras Blancas until about day 17, and thereafter drifted offshore leaving most of the range south of Point Piedras Blancas untouched.

Conclusions and recommendations

Oil spills may be an unavoidable consequence of tanker transport of oil. Historical data suggest that it might be prudent to prepare for one or more spills of 1,000 to 100,000 bbls in the near future. Spills in this range can have a significant impact on the sea otter population. How can the threat be reduced? The U. S. Coast Guard (1996) states that implementation of the Oil Pollution Act of 1990 (OPA 90) regulations over the next several years is expected to greatly reduce the probability of vessel casualties and associated oil spills. Some lessening of the occurrence rate of oil spills may indeed result; however, it would be unrealistic to hope that OPA 90 regulations will eliminate all threat of large oil spills.

It appears unlikely that the U. S. Coast Guard will achieve, in the near future and with concurrence of the International Maritime Organization, a new Traffic Separation Scheme in and out of San Francisco Bay. Nor will a Shipping Fairway be established along the central California coast. However, this does not mean that tankers must take the most direct route. The Western State Petroleum Association (WSPA; as cited in U. S. Coast Guard 1996) has recommended a stand-off distance of at least 50 nmi in agreement with the State of California. If adhered to by the oil companies and their tankers, this would result in a substantial decrease in risk of oil spills to sea otters.

Figure 3. Suggested changes to tanker routes around sea otter habitat.

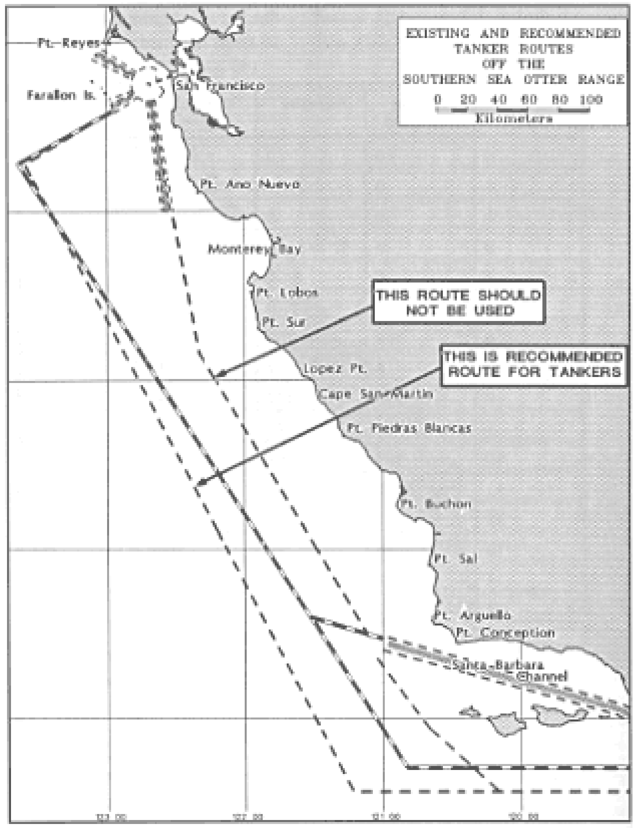

Figure 3. Suggested changes to tanker routes around sea otter habitat.

Based on the results of Ford and Bonnell (1995) it is clear that a change in tanker routing would be the most effective way to reduce potential of impact of oil spills on southern sea otters. The recommended route (see Figure 3) skirts the edge of the one-percent contour for contact with the sea otter range (Ecological Consulting, Inc. 1990; see Saunders, this issue). Small, almost negligible, costs would be incurred by tankers due to extra time at sea. These additional costs pale in comparison to those incurred should a spill occur within these bounds. WSPA and oil companies do not have to wait for mandate from the U. S. Coast Guard‹take initiative now and choose the route that best reduces the potential for impact on sea otters.

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