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
Allan J. Brody

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

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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.

A simple model of oil spill mortality based on distance.

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 ($R^2=0.73$, $F=17.5$, $p=0.009$), 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.

<u>Available data</u>.

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.

<u>No data available</u>.

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.

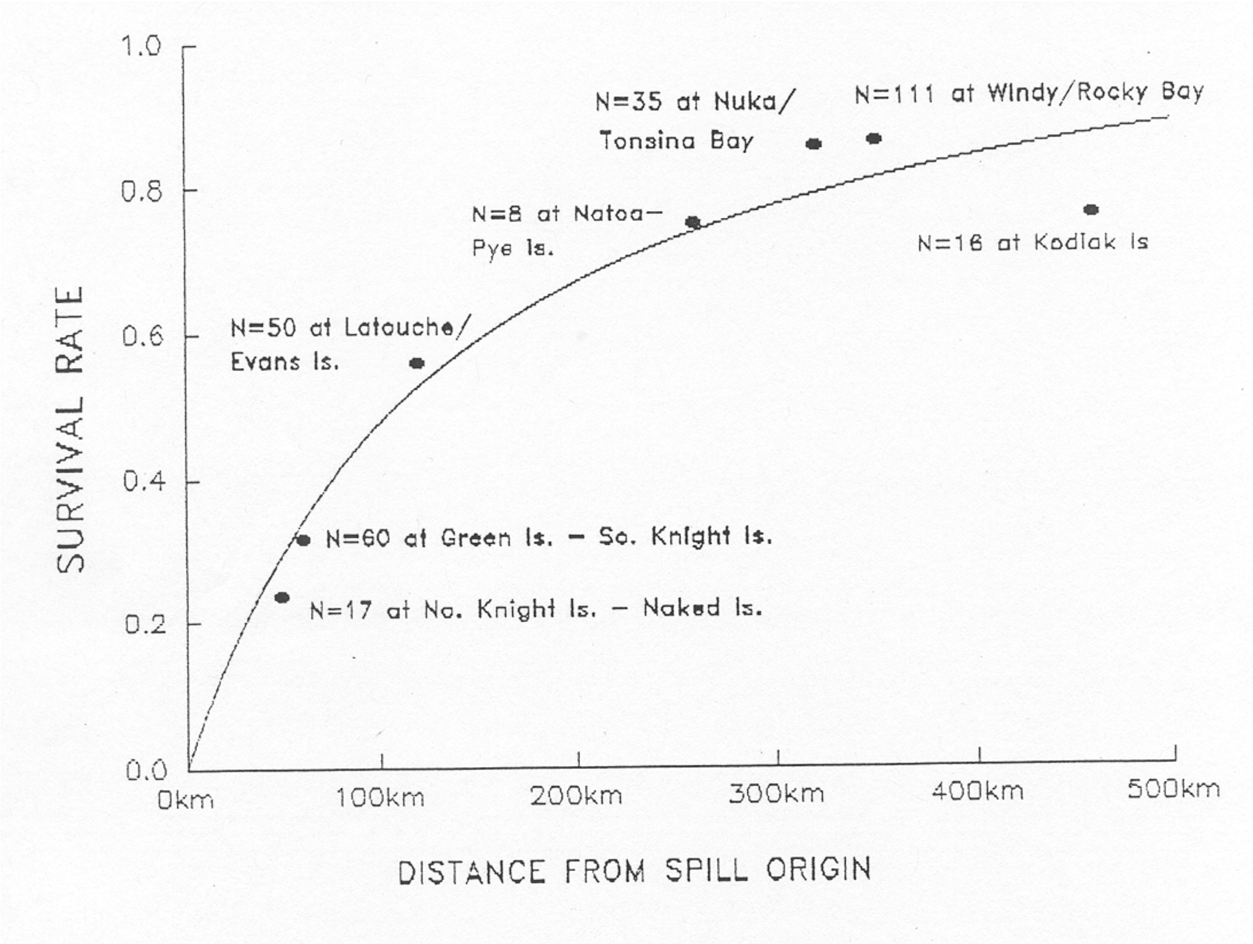


Figure 2. Relative risk of an 11 million gallon oil spill affecting 140 kilometers of coast as a function of location along the 5-fathom line. Y-axis is the predicted number of deaths, assuming a range-wide population of 2101 animals.

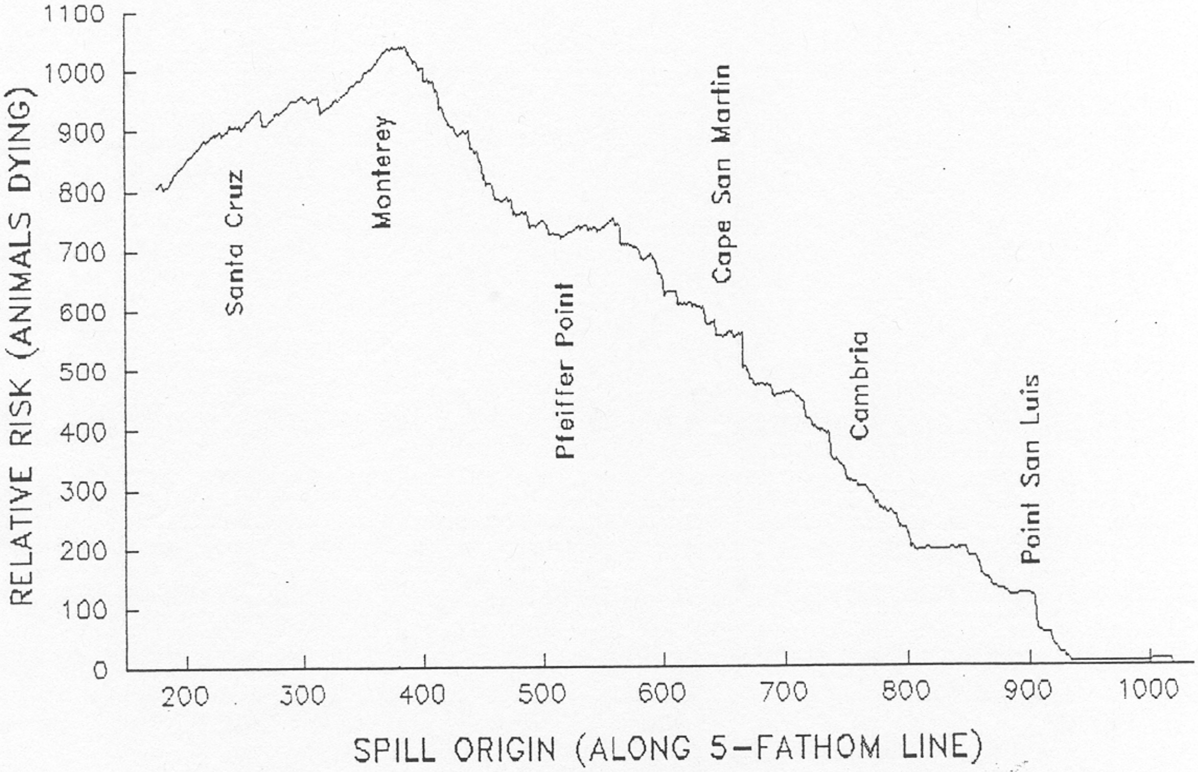


Table 2. Summary of predicted effect of an 11 million gallon oil spill occurring near the tip of the Monterey Peninsula, according to the simple model of mortality as a function of distance from spill origin. Based on Ford′s (1985) relationship between spill volume and length of coast affected, the relationship 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.

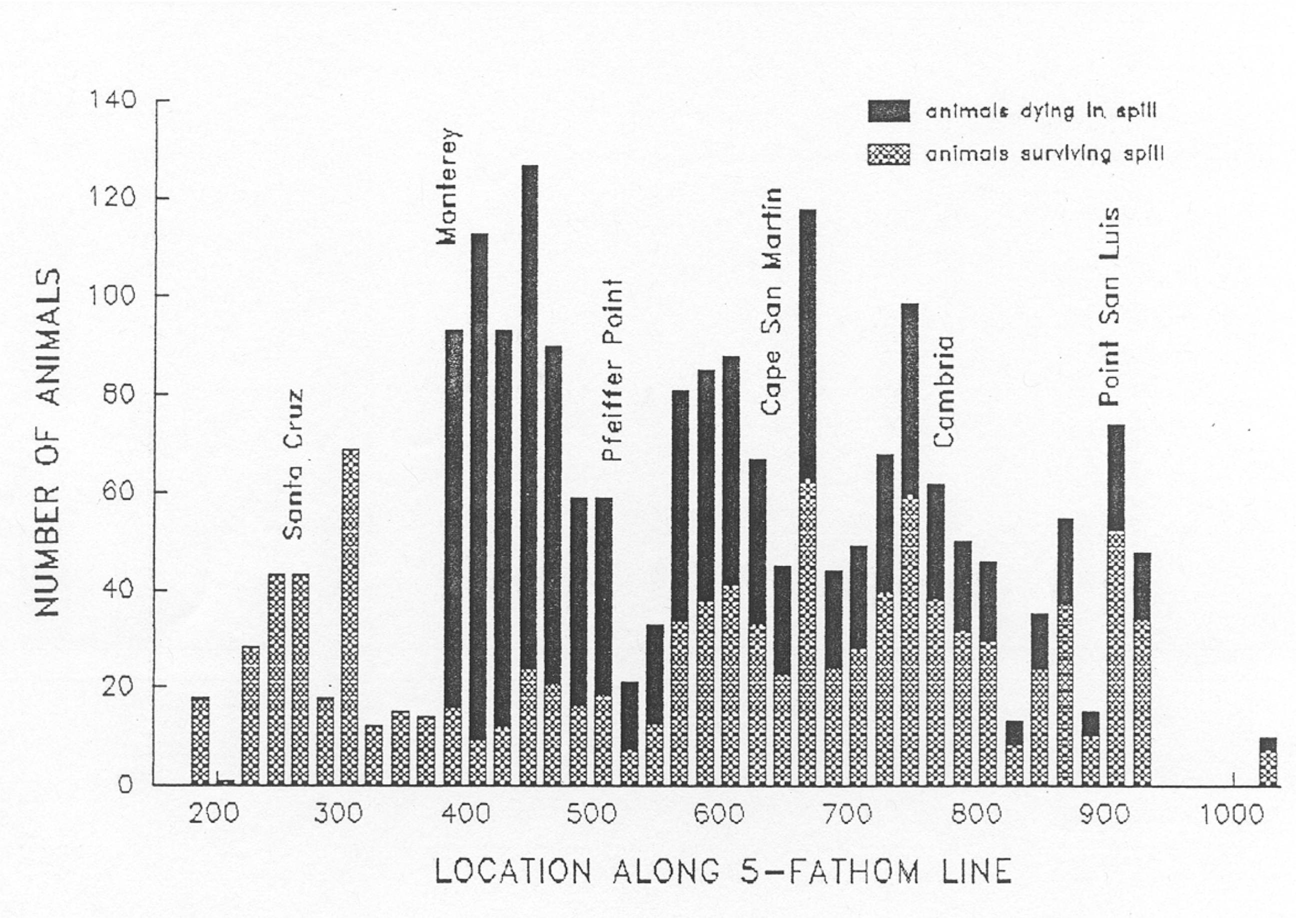


Figure 4. “Survivorship curve” for 105 sea otters first exposed to oil on approximately day 5 of EVOS in western Prince William Sound and subsequently captured.

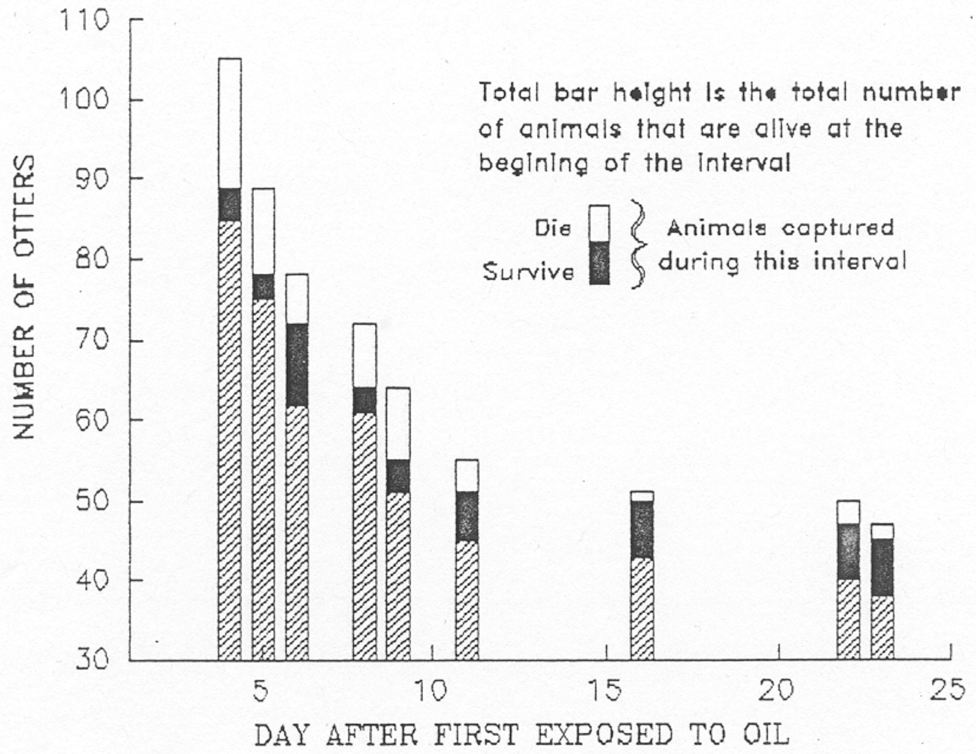


Table 3. Calculations used in estimating daily survival rates for 105 captured sea otters that were first exposed to oil on approximately day 5 of EVOS in western Prince William Sound.

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.

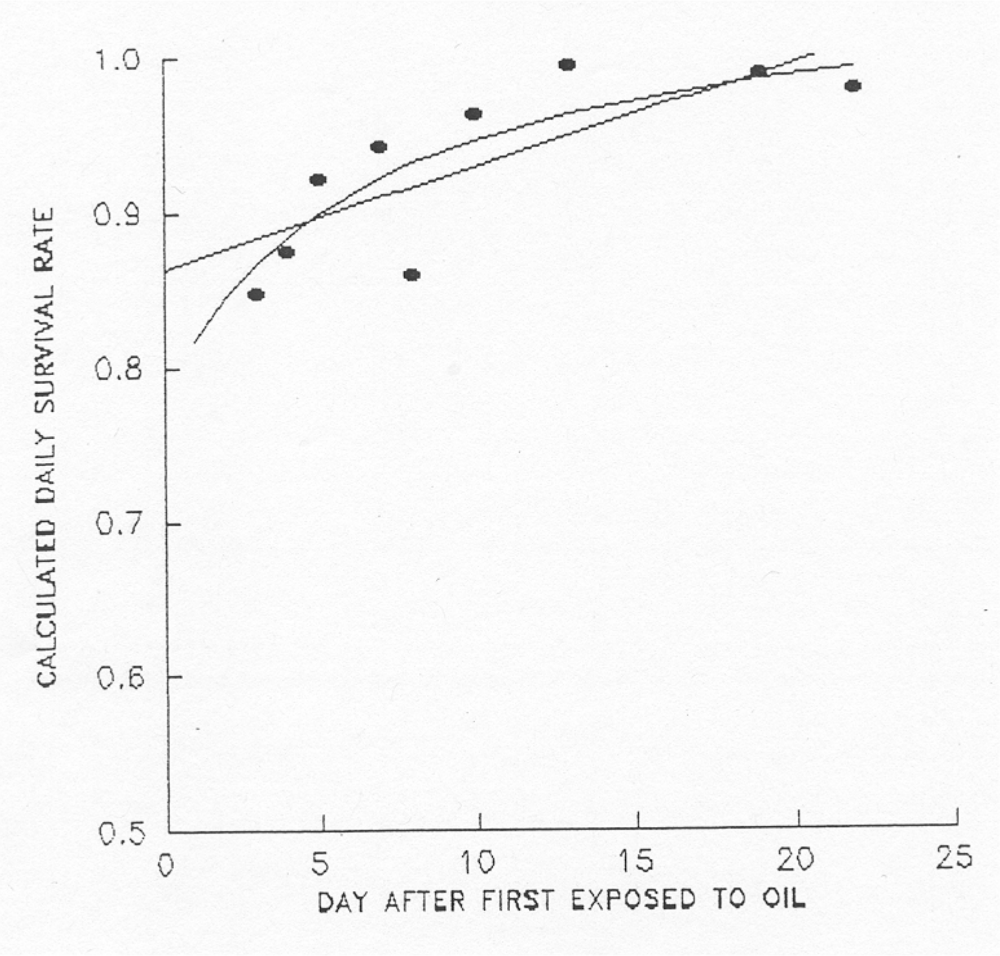


Figure 6. “Survivorship curve” for 109 sea otters first exposed to oil on approximately day 18-20 of EVOS off the Kenai Peninsula and subsequently captured.

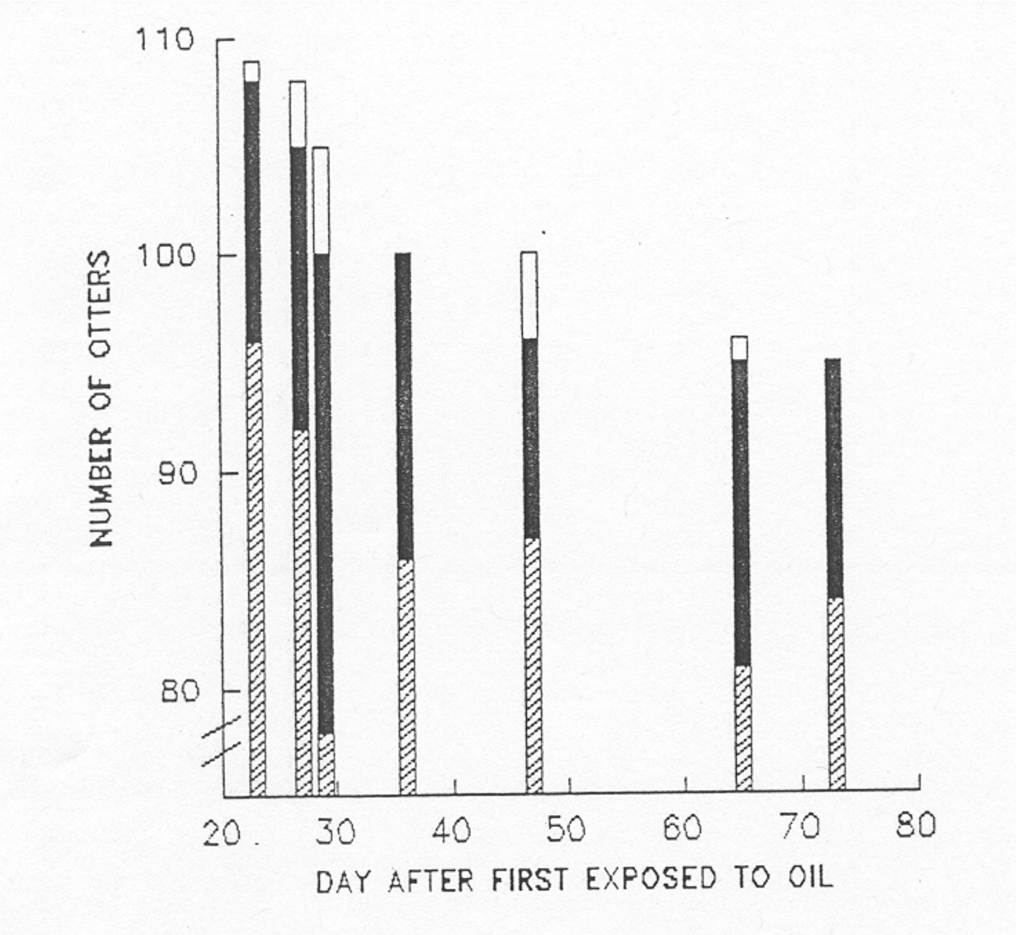


Table 4. Calculations used in estimating daily survival rates for 109 captured sea otters that were first exposed to oil on approximately day 20 of EVOS on Kenai Peninsula.

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.

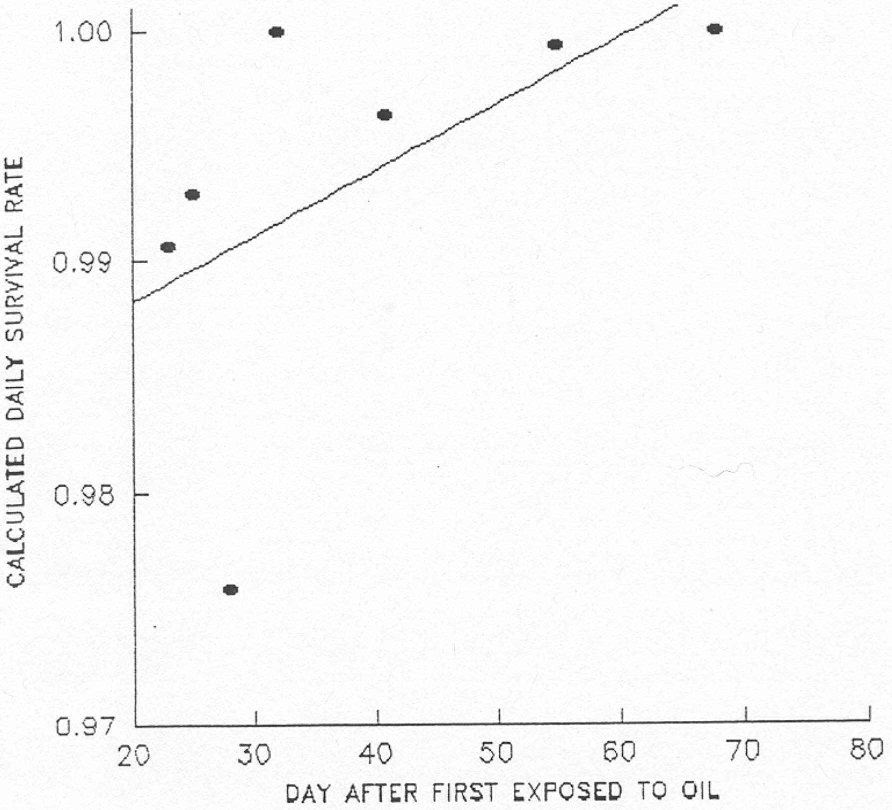


Figure 8. Calculated daily survival rates for 214 sea otters captured in rescue efforts after EVOS as a function of the age of the oil they were exposed to. Solid regression line is the “Michaelis Menton” relationship, dashed line is the log transformation.

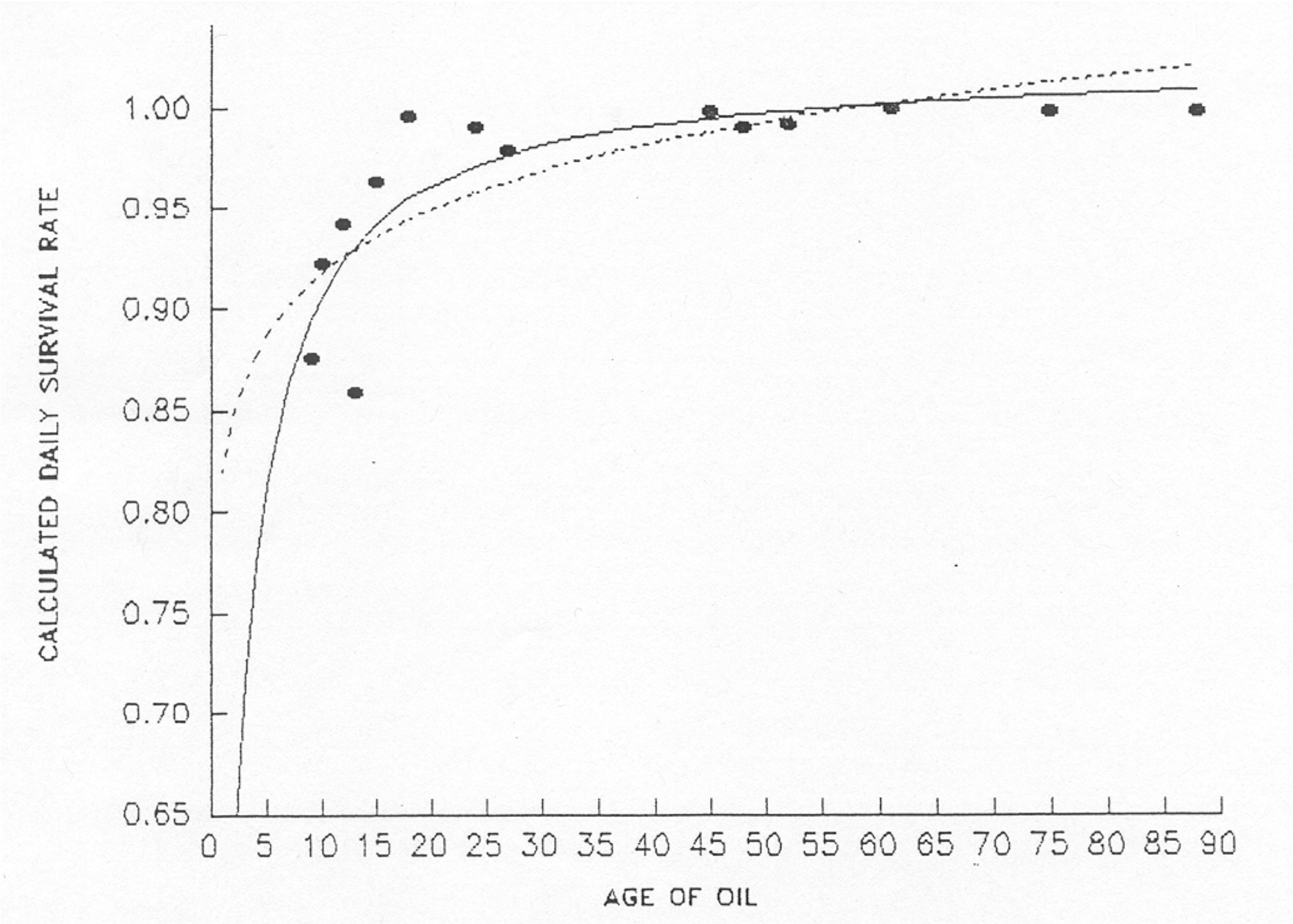
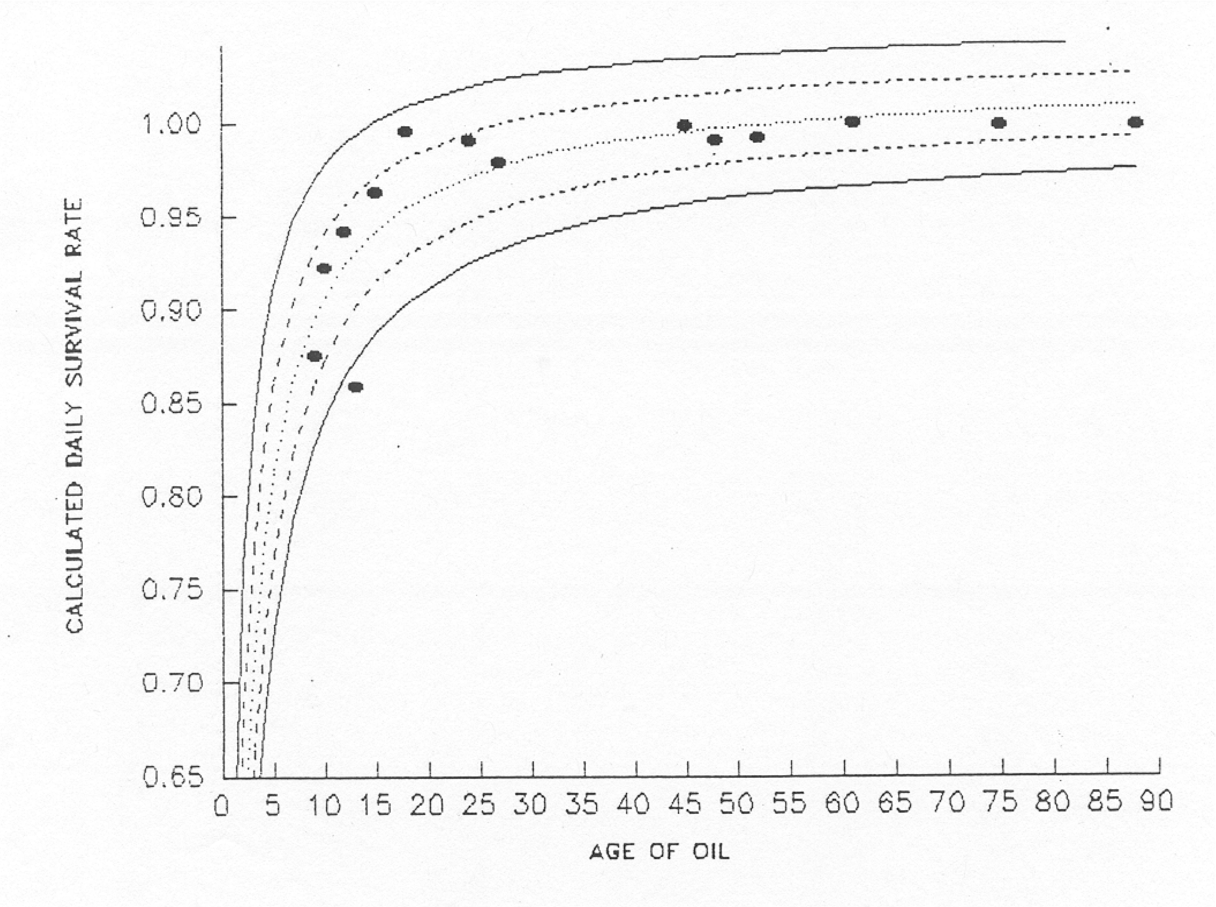


Figure 9. “Michaelis-Menton” regression relationship for daily survival rates of 214 sea otters captured in rescue efforts after EVOS as a function of the age of the oil they were exposed to. Dotted line is median estimate, dashed lines are +/- 1 standard error, solid lines are +/- 2 standard errors.



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	.