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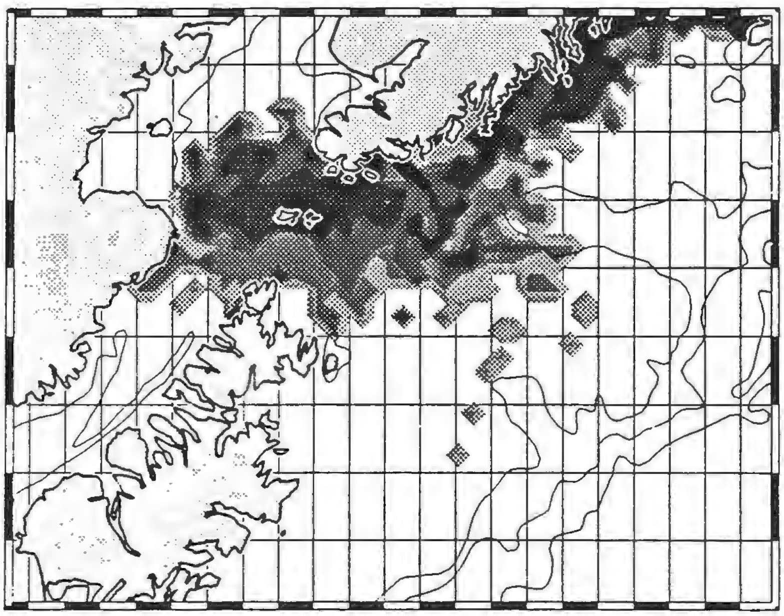
Assessment of Direct Seabird Mortality in Prince William Sound and the Western Gulf of Alaska Resulting from the *Exxon Valdez* Oil Spill



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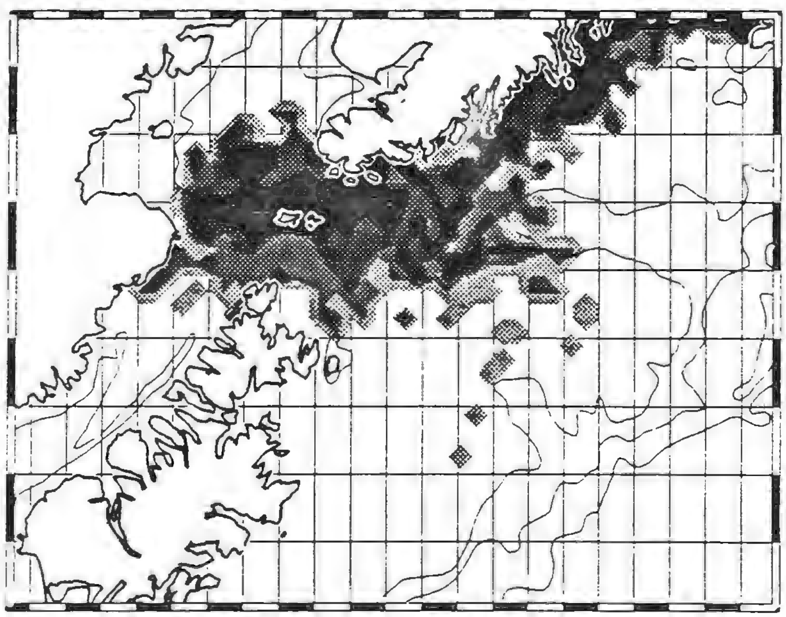

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ACRONYMS AND ABBREVIATIONS

ADNR	Alaska Department of Natural Resources
AF&G	Alaska Department of Fish and Game
AGL	above ground level
ANOVA	analysis of variance
ASL	above sea level
bbls	barrels
cm	centimeter
ESI	Environmental Sensitivity Index
ft	feet
g	gram
gal	gallon
GIS	Geographic Information System
h	hour
HAZMAT	Hazardous Material
km	kilometer
kn	knot
L	liter
LORAN	Long Range Navigation
m	meter
MHz	megahertz
mL	milliliter
mm	millimeter
nmi	nautical mile
NOAA	National Oceanic and Atmospheric Administration
NODC	National Oceanographic Data Center
NPS	National Park Service
NWR	National Wildlife Refuge
OCSEAP	Outer Continental Shelf Environmental Assessment Program
OSSM	On Scene Spill Model
oz	ounce
PEN	Peninsula
PW	Prince William Sound
RPI	Research Planning Institute
S.D.	standard deviation
USFWS	U.S. Fish and Wildlife Service
VLF	Very Low Frequency

1.0 INTRODUCTION

On 24 March 1989, the *Exxon Valdez* spilled at least 260,000 barrels of Prudhoe Bay crude oil into some of the most densely occupied marine bird habitats in the world (Piatt et al., 1990). The first area affected was Prince William Sound, where hundreds of thousands of loons, grebes, sea ducks, and murrelets were wintering in sheltered coastal waters (Forsell and Gould, 1981; DeGange and Sanger, 1986). Driven by prevailing winds, the oil moved in a southwesterly direction, contaminating the shorelines of Knight, Green, and LaTouche Islands and parts of the mainland shore. Although much of the oil beached in Prince William Sound, a large quantity was moved by winds out of the Sound through Montague Strait and was eventually deposited onto beaches of the Kenai Peninsula, the Barren Islands, the Kodiak Archipelago, and the Alaska Peninsula. These waters support more than a million alcids, cormorants, kittiwakes, petrels, and fulmars, which have major colonies along the coast (e.g., Sowls et al., 1978). The area is also part of a major migratory pathway for the many million birds that summer in the Bering, Chuckchi, and Beaufort Seas. Most of the mortality of seabirds occurred in these waters (Piatt et al., 1990).

Two methods can be used to determine total mortality of seabirds following an oil spill: (1) comparisons can be made between populations present in an area before and after the spill, and (2) estimates of total mortality can be made based on the actual number of seabirds recovered following the spill. The first approach is practical for colonies that are known to be hard hit and where accurate prespill estimates of colony size are available. To the extent that mortality is spread out over a large number of colonies or that colony size is either poorly known or fluctuates significantly due to natural causes, the second method of assessment is the only alternative. This approach does not require an estimate of the size of the population at risk, but it does require estimates of the rate at which bird carcasses are lost due to factors such as sinking or scavenging at sea, scavenging on land, and insufficient search efforts.

We began this study by addressing some identified data gaps related to these sources of undercounting. These gaps included rates of loss of carcasses at sea and on land and variations in the effectiveness of the beach search effort. We also considered it important to reassess the adequacy of counts of oiled carcasses by examining a portion of the carcasses collected following the spill. Information from these studies was then used in a general damage assessment model to estimate total mortality. The model for the *Exxon Valdez* spill was similar to models we have constructed for other oil spills (e.g., Dobbin et al., 1986; Ford et al., 1987, 1991; Page and Carter, 1986; and Page et al., 1990), but its application was improved by having more precise values of input parameters. We used the National Oceanic and Atmospheric Administration's (NOAA) Hazardous Material (HAZMAT) On Scene Spill Model (OSSM) to describe the extent of the spread of oil, and Outer Continental Shelf Environmental Assessment Program (OCSEAP) data on the pelagic population of birds in the affected area.

The work discussed in sections to follow constitutes Bird Study Number 1, conducted for the U.S. Fish and Wildlife Service (USFWS) by Ecological Consulting, Inc., Portland, Oregon. The work began in the spring of 1990 with field studies in Prince William Sound and the Gulf of Alaska, which were completed in August 1990. Subsequently, we conducted a further examination of the carcasses, analyzed records of the beach search effort, mapped the beach search effort against the distribution of shoreline types, described pelagic distribution of birds from OCSEAP data, and conducted simulation model runs. The results of each of these study components are discussed in sections 3 through 5. The findings have been used to develop estimates of the rates of various processes affecting carcass loss, to correct for variation in beach search efforts, and to describe more fully the area where oil contacted foraging or migrating seabirds. Once values were determined, they were used in a synthesis model to generate estimates of mortality and to examine sensitivity of modeling procedures to uncertainty in values of input parameters.

2.0 STUDY FRAMEWORK

2.1 Overview

Seabirds killed by oil drift at sea until they sink or are cast ashore. Once ashore, a carcass may be removed by scavengers, or it may persist for some period of time. If it persists, searchers may or may not find it. The basic model structure (figure 2-1) is an inverse of this process. Working backwards from the carcasses recovered on a particular beach on a particular day, we first estimate how many carcasses were deposited before the toll taken by scavengers. Using this amount as an estimate of the number of carcasses originally present on the beach, we extrapolate these numbers to nearby unsearched beaches. Finally, we look at the oil-spill trajectories leading to that beach on that day and determine when the trajectory intersected known concentrations of living birds. This information indicates how long the bird carcasses were at sea before beaching; this time can then be used to estimate the number of carcasses lost enroute to the beach.

2.2 Scale and Segmentation of Data Sets

Data sources used in this analysis vary widely in terms of their degree of spatial resolution. Our most spatially detailed data set is the shoreline typing data (Environmental Sensitivity Index (ESI)) provided to us by the State of Alaska. These data are digitized to a resolution of about 0.2 kilometers (km). For comparability with other data sets, we binned these data into 15′ latitude x 15′ longitude blocks (27.2 km north-south x 14.3 km east-west). Locations of carcass recovery sites in the morgue data bases are of variable resolution. Where the recovery effort is described using small geographic features such as small bays or coves, the resolution is on the order of 1 to 2 km. When larger features are used or when local place names are more widely spaced, such as around Cape Douglas, the resolution may be only 10 to 20 km. For analysis of distributional data, we used a version of the OCSEAP/USFWS data base divided into 30′ latitude x 30′ longitude blocks, about 54.3 km

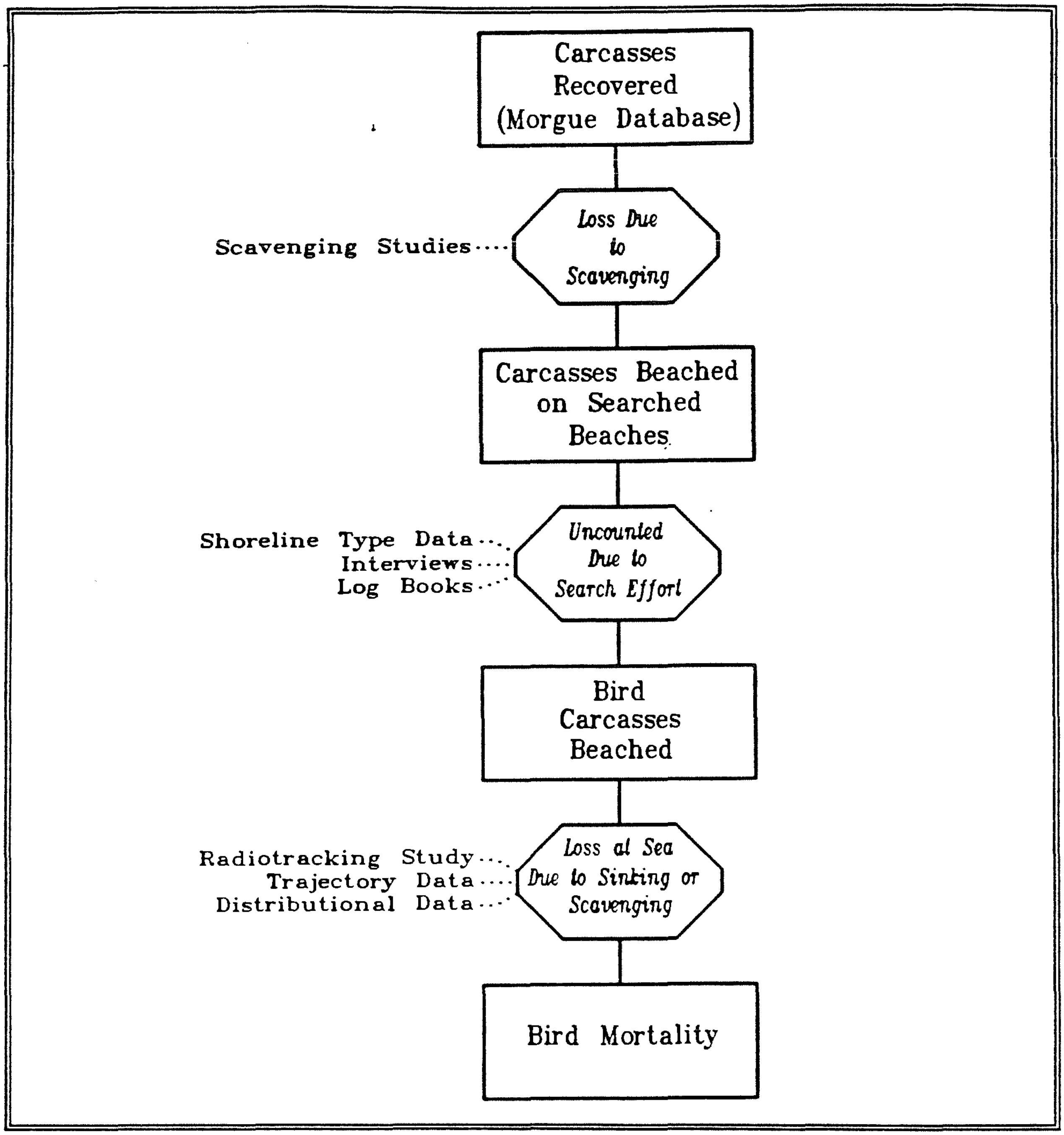


FIGURE 2-1. Organization of damage assessment model showing processes and information sources. Natural processes occur in order from bottom to top, model reconstruction proceeds from top to bottom.

north-south x 28.6 km east-west. The OSSM uses a gridded version of land in which each grid cell is either land or water. Lagrangian elements were tracked by OSSM beached along the borders of these grid cells, which are 5.4 km north-south x 3.0 km east-west. For comparability with distributi   al data, v   so bin   d these data from the OSSM model into 30′ latitude/longitude blocks. Finally, an   tal information and interviews tended to refer to regions of human jurisdiction, such as National Parks and Wildlife Refuges, of which the scales are relatively large compared to other data sources.

Because the starting point of the analysis was the morgue data base, our approach was to take the position specified in a morgue record and to look it up in other data sets as needed. Thus, a morgue record would be characterized as occurring in a region characterized by the surrounding 15′ latitude/longitude block. The morgue record would be linked to oil-spill trajectories arriving within the surrounding 30′ latitude/longitude block. Data relating to the search effort would be based on the human jurisdiction in which the morgue record occurred.

2.3 The Morgue Data Base

Model computations build upon the information provided by the morgue data base. This data base consists of the records kept by personnel at four bird collection centers as recovered carcasses were logged into their custody. Four centers operated at various times during the recovery effort, in Valdez, Seward, Homer, and Kodiak. Although each center generally collected carcasses from the surrounding local area, some overlap occurred because the centers were in operation for different periods of time. Through the USFWS (John Piatt), we received digital copies of the data bases as compiled by the centers. Some files were in dBASE format, and some were in Lotus format. The information collected differed somewhat from center to center. A comparison of the information collected is provided in table 2-1. In all four data bases, many birds were collected from unknown locations, and specificity of location data varied greatly. The date of collection was also frequently missing. In some cases, fields were provided that were rarely or never used, such as sex, oiling, and old versus recently dead. Species, count, and processing date proved to be most consistently available. Number scavenged was consistently provided by the Kodiak records. More complete records may be enclosed with individual frozen bird carcasses in the morgue freezer vans.

Because of the uncertainty about the completeness of morgue records and to provide information on the degree of oiling and of decomposition, we reexamined a subsample of the carcasses. The results of this examination are presented in section 3.0.

3.0 REEXAMINATION OF CARCASSES RECOVERED

3.1 Introduction

Following the oil spill, dead birds were retrieved from shorelines and open waters in Prince William Sound and along the Kenai Peninsula, Kodiak Island, and Alaska Peninsula by fishermen under contract to the Exxon Oil Company and by personnel from several Government agencies. The birds were transported to morgues where they were examined, placed in plastic bags, and then stored in freezer vans. Piatt et al. (1990) reported that about 36,000 dead birds were recovered between 24 March and mid-September. The lack of discernible oil on the plumage of some birds, temporal changes in the species composition, and reports of natural dieoffs (Sanger, 1989) indicated that not all collected birds were necessarily victims of the spill. Piatt et al. (1990) hypothesized that most birds retrieved after 1 August were unoiled individuals of surface-feeding species that probably died of starvation rather than from effects of the oil. Because the data collected when carcasses were logged into morgues did not include information on the degree of carcass oiling, Piatt et al. (ibid) established a cutoff date of 31 July to divide probably oiled birds from unoiled birds. They assumed that all birds collected before this date were killed by oil, while those collected afterwards died of other causes.

In fact, the time periods in which oiled and unoiled birds appeared at the morgues probably overlapped with unoiled birds becoming relatively more abundant over time. In order to examine the validity of the 31 July cutoff date, we examined 3,000 frozen carcasses stored in two freezer vans in Anchorage, Alaska. Additionally, about 8 percent of the carcasses logged into the morgue before 1 August were not identified to taxa (Piatt et al., 1990); they were simply listed as birds. Some of these specimens were identified more precisely by reexamining carcasses. Carcass reexamination was also used to refine the identity of other carcasses currently listed in the morgue logs, to record information on the degree of decomposition and completeness of logged carcasses, and to obtain information on carcass condition. This information provided clues for interpreting how long carcasses had been floating in the water or cast up on the beach before being collected.

3.2 Disposition of Carcasses in Freezer Vans

Carcasses collected after the spill are stored in five freezer vans according to the area from which they were collected: carcasses from Prince William Sound in one van (Valdez van), carcasses from the Seward Peninsula in one van, carcasses from the Barren Islands in one van (Homer van), and carcasses from the Kodiak Island and Alaska Peninsula regions in two vans. The bags of carcasses are stored and labeled differently in the five vans. The bags in the Homer and Seward freezers are stored in totes (4 feet (ft) by 4 ft by 3 ft) that are stacked two totes high. Because bags are sometimes frozen together, their removal is difficult. Also, totes are not labeled; determining whether they contain marine mammals or birds is not easy. Bags of birds in the other freezer vans are piled on the floor. Bags on the bottom of the pile tend to be frozen together and to the floor of the van; they must be pried apart before they can be removed. Bags from Prince William Sound are labeled only with the date on which the birds were logged into the Valdez morgue. Often, several bags have the same date because of the large number of birds coming into the morgue. The bags in the Kodiak morgues are labeled with a number and, usually, a date. Frequently, the number and kinds of birds contained in the bag are also on the label. A log from the Kodiak morgues has a record of the bag numbers, the date the carcasses were placed in the freezer van, the number of each species in the bag, the number of carcasses that were scavenged, and usually the collection date and location. Based on the numbers reported in the morgue data base, the following numbers of birds (approximately) are stored in each van: about 3,358 in the Prince William Sound (Valdez) van; 3,503 in the Kenai Peninsula (Seward) van; 5,480 in the Homer van; and 22,636 in the Kodiak-Alaska Peninsula vans.

3.3 Sampling Carcasses

We examined carcasses from 193 bags in the two Kodiak-Alaska Peninsula vans. We limited our reexamination of carcasses to this region for the following reasons: (1) a sample of carcasses could be obtained in the Kodiak-Alaska Peninsula vans with greater ease than the other vans; (2) the amount of information available on the contents of each Kodiak-Alaska Peninsula bag was greater than for the other regions; and (3) these two vans contained the majority of the total carcasses from the entire spill region. Before removing bags for examination, we reviewed the log of the contents of each bag. Based on this review, we selected a set of bags for possible examination. Selections were made to ensure that bags were scattered geographically over the Alaska Peninsula and Kodiak Island regions and temporally over the period from late April to mid-September. Almost every bag with the earlier dates was filled primarily with murres. We selected bags that also contained at least one other taxon, knowing that we would also sample murres in the process. Other taxa that we targeted in the selection process included unidentified murrelets, unidentified cormorants, unidentified birds, shearwaters, gulls, storm-petrels, and puffins. Natural dieoffs were suspected for gulls, shearwaters, storm-petrels, and puffins (Piatt et al., 1990) later in the spill period when these species tended to dominate the samples and murres became relatively rare. Consequently, we found it necessary to look for bags that contained at least one murre in samples from mid-July onward to obtain a sufficient sample of murres for the later spill period. In all cases, we tried to select bags with 40 or fewer carcasses to minimize the time required for thawing the carcasses. Because carcasses were almost never individually bagged, they tended to be frozen in a solid block. We targeted about three times as many bags as we had time to examine. Locating all specified bags, whatever their number, would have been too time consuming because their arrangement in the vans had no organization. Any bag on the target list for sampling was set aside for examination when it was encountered during a search of the vans. We searched through the length, breadth, and width of the piles of bags in the vans to ensure that the sample of bags we actually obtained was scattered throughout the list. The bags were then taken to a warehouse where the contents were thawed for examination.

3.4 Defining a Carcass

While some carcasses were whole, many were missing heads, wings, or legs. Bags also contained miscellaneous legs, heads, sterna, and other body parts. As we spread partial carcasses out on the examination table, we placed any loose wings, legs, or heads from the bag with the partial carcasses to make them as "complete" as possible. In placing carcass fragments together, we had no way to determine if the fragments were actually from the same individual. Some carcasses were pieced together with up to seven parts. At the other extreme, some were represented by a single part such as a wing, a leg and foot, a head, and (in many cases) only a sternum. The piecing together of carcasses produced the minimum number of specimens that we could easily ascertain to be represented by the carcass fragments in a bag. After 2 days of examination, we recognized the necessity of listing all the parts used to construct a carcass and began consistently recording this information.

3.5 Data Recorded

Before examining carcasses, we recorded the contents that were logged for each bag on our data sheets. We then tried to match the contents of the bag with the logged contents. Each "carcass" was identified as closely to species as our ability permitted. Degree of decomposition, extent and location of oiled plumage, and carcass completeness were also recorded. Carcasses were categorized as follows: fresh and intact; rotting but with some flesh; skin, bones, and feathers only; or bones only. Carcasses were recorded as having some oil on their plumage, having no oiled plumage, or as being unknown regarding oiled plumage. The latter applied to all carcasses represented only by bones whether or not the bones were coated with oil. A small proportion of the carcasses, which had small amounts of oil on their plumage where they touched other oiled carcasses in the bag, may have not been killed by the oil. We noted all carcasses that we thought might have been oiled only by contact with other carcasses. Degree of oiling was coded: code 0 for no oiled plumage; code 1 for less than 2 percent of the plumage oiled; code 2 for 2 to 33 percent of the plumage oiled; code 3 for 33 to 66 percent of the plumage oiled; and code 4 for 66 percent or more of the plumage oiled. The location of the oil was described by codes that indicated general body regions, such as dorsally only, wings only, dorsally and ventrally, entire body, etc. We also recorded all dates and locations of carcass collection indicated in logs and on data sheets on the bags.

3.6 Results of the Examination of Bag Contents

Although 3,378 carcasses were logged for the 193 bags we examined, we found only 3,243 carcasses; discrepancies in numbers of carcasses occurred for 123 of the 193 bags. We found 97 carcasses that were not reported, but failed to find an additional 232 carcasses that were recorded in the log (table 3-1). About one-half the carcasses that we failed to find were logged as unidentified birds, which were probably represented originally only by feathers, and therefore would not register as a carcass using our methods. The differences in numbers were also probably caused by the pooling of carcass fragments (over which we had no control) from more than one location or collection date for storage in the same bag. When we pieced carcasses together, we had no way of determining whether all the parts came from the same location or date. At least 62 of the 123 bags with differing numbers contained carcasses from two or more locations or collection dates. However, the pooling of carcass fragments from multiple collection locations or dates would not be expected to produce any of the extra 97 carcasses not reported in the original examination but detected in our reexamination. Many additions were murres (table 3-1), the predominate species in a majority of the bags we examined.

Murres were the predominate taxa affected by the spill (Piatt et al., 1990). We accounted for 1,788 murres in bags that reportedly contained 1,780 murres. Although we failed to find 68 murres that were reported to be in the bags, we found 37 that were not reported (table 3-1). Other changes, when combined, resulted in the revised murre total: 18 carcasses initially listed as murres were changed to other taxa, and 1 carcass listed as a Parakeet Auklet was changed to a murre (table 3-2); 15 carcasses originally identified as alcids were murres (table 3-3); 45 carcasses identified as birds were changed to murres

TABLE 3-1. Number of additions and deletions to the logged carcasses resulting from the post-spill carcass examination. Parentheses indicate cases for which we were not certain of the identity of a carcass.

	ADDITIONS	DELETIONS
Loon	2	
Sooty Shearwater		1
Short-tailed Shearwater	1	
Shearwater	1	8
Fork-tailed Storm-Petrel	9	
Storm-Petrel	4	2
Cormorant	1	1
White-winged Scoter	1	
Duck	5	1
Black Oystercatcher		1
Glaucous-winged Gull	1	
Black-legged Kittiwake	1 (2)	5
Gull	5 (1)	4
Murre	36 (1)	68
Pigeon Guillemot	2	1
Kittlitz's Murrelet	1	
Brachyramphus sp.	2	
Ancient Murrelet	5	
Least Auklet	1	
Tufted Puffin		1
Puffin	1	1
Alcid	2	20
Eagle		1
Peregrine Falcon		1
Willow Ptarmigan	2	
Northwestern Crow	1	
Passerine	1	
Bird	8	116
TOTAL	93 (4)	232

TABLE 3-2. Number of taxa changes resulting from the post-spill examination of carcasses. Parentheses indicate errors in the original classification of a carcass for which we could assign only a probable new identification.

TAXA CHANGE	NUMBER
Yellow-billed Loon to Common Loon	1
Loon to Alcid	1
Sooty Shearwater to Short-tailed Shearwater	17
Short-tailed Shearwater to Sooty Shearwater	6
Shearwater to Black-legged Kittiwake	2
Shearwater to Gull	0 (1)
Storm-Petrel to Dowitcher	1
Storm-Petrel to Ancient Murrelet	1
Double-crested Cormorant to Red-faced Cormorant	1
Pelagic Cormorant to Red-faced Cormorant	3
Cormorant to Loon	1
Cormorant to Gull	1
Common Eider to King Eider	0 (1)
Scoter to Common Eider	1
Merganser to Cormorant	2
Short-billed Dowitcher to Wandering Tattler	1
Mew Gull to Cormorant	1
Mew Gull to Black-legged Kittiwake	1
Mew Gull to Red-legged Kittiwake	0 (1)
Glaucous-winged Gull to Mew Gull	1
Gull to Northern Fulmar	1 (1)
Aleutian Tern to Arctic Tern	1
Murre to Cormorant	1
Murre to Shearwater	3
Murre to Duck	0 (1)
Murre to Black-legged Kittiwake	1
Murre to Gull	1
Murre to Pigeon Guillemot	3 (1)
Murre to Ancient Murrelet	1
Murre to Rhinoceros Auklet	1 (1)
Murre to Puffin	4
Pigeon Guillemot to *Brachyramphus* Murrelet	1
Marbled Murrelet to Ancient Murrelet	1
Ancient Murrelet to Marbled Murrelet	1
Parakeet Auklet to Murre	1
Alcid to Shearwater	4
Alcid to Storm-Petrel	4
Alcid to Black-legged Kittiwake	2
Northwest Crow to Cormorant	1
Northwest Crow to Shearwater	1
TOTAL	75 (7)

TABLE 3-3. Number of taxa refinements resulting from the post-spill examination of alcids.

TAXA CHANGE	NUMBER
Alcid to Murre	15
Alcid to Pigeon Guillemot	6
Alcid to Horned Puffin	1
Alcid to Puffin	4
Small Alcid to Marbled Murrelet	7
Small Alcid to Kittlitz's Murrelet	2
Small Alcid to *Brachyramphus* Murrelet	22
Small Alcid to Ancient Murrelet	33
Small Alcid to Cassin's Auklet	3
Small Alcid to Parakeet Auklet	2
Small Alcid to Least Auklet	2
Puffin to Tufted Puffin	2
TOTAL	99

(table 3-4); and 4 carcasses originally called murres were changed to alcids (table 3-5). In many cases, we refrained from identifying murres to species because of the degree of decomposition and the large amount of oil coating the carcasses. Common Murres predominated over Thick-billed Murres in the sample of murres that were identified to species. We combined all murres in the following analyses to eliminate the problem of dealing with large numbers of murre carcasses that could not be identified to species.

3.7 Taxa Changes Resulting From Carcass Reexamination

3.7.1 Erroneous Identifications

We found 82 instances where we believed the original identification of carcasses had been erroneous. These cases represent only 2.5 percent of the carcasses recorded in our examination, a good level of accuracy considering the overwhelming numbers of birds that were processed at the morgues during the height of the oil spill. The most common source of

TABLE 3-4. Number of taxa refinements resulting from the post-spill examination of carcasses initially listed only as bird.

TAXA	NUMBER
Loon	1
Northern Fulmar	2
Sooty Shearwater	2
Short-tailed Shearwater	1
Shearwater	35
Fork-tailed Storm-Petrel	11
Storm Petrel	9
Cormorant	11
Mallard	1
Duck	3
Western Sandpiper	1
Mew Gull	1
Glaucous-winged Gull	1
Black-legged Kittiwake	10
Gull	4
Murre	45
Pigeon Guillemot	10
Marbled Murrelet	1
Kittlitz's Murrelet	2
Brachyramphus Murrelet	9
Ancient Murrelet	2
Cassin's Auklet	2
Parakeet Auklet	2
Horned Puffin	1
Tufted Puffin	1
Puffin	6
Alcid	5
Northwestern Crow	2
Common Raven	1
Varied Thrush	3
Wilson's Warbler	2
Crossbill	1
Passerine	9
TOTAL	197

TABLE 3-5. Number of taxa generalizations resulting from the post-spill examination of carcasses.

TAXA GENERALIZATIONS	NUMBER
Sooty Shearwater to Shearwater	4
Short-tailed Shearwater to Shearwater	10
Fork-tailed Storm-Petrel to Storm-Petrel	1
Harlequin Duck to Duck	1
Common Eider to Duck	1
King Eider to Duck	1
Mew Gull to Gull	1
Murre to Alcid	4
Marbled Murrelet to Alcid	1
Ancient Murrelet to Alcid	1
Marbled Murrelet to *Brachyramphus* Murrelet	1
Tufted Puffin to Puffin	1
Alcid to Bird	1
TOTAL	28

confusion was between Sooty and Short-tailed Shearwaters. Overall, we identified 40 types of misidentified taxa (table 3-2).

3.7.2 Refining Identifications

We were able to improve the identifications of 360 (11 percent) of the carcasses we examined (tables 3-3, 3-4, and 3-6). These reclassifications included 99 changes to alcids, the most common of which were from small alcid to either Ancient Murrelet or *Brachyramphus* Murrelet and from alcid to murre (table 3-3). Forty changes were possible for miscellaneous taxa. By far the most important change was from unidentified shearwater to Short-tailed Shearwater (table 3-6). We were able to improve the identifications of 197 carcasses originally listed only as bird. Murres, shearwaters, storm-petrels, cormorants, Pigeon Guillemots, and Black-legged Kittiwakes collectively accounted for the majority of these changes (table 3-4).

TABLE 3-6. Number of taxa refinements resulting from the post-spill exam[illegible]n of miscellaneous taxa.

TAXA CHANGE	NUMBER
Shearwater to Short-tailed Shearwater	40
Shearwater to Sooty Shearwater	1
Petrel to Fork-tailed Storm-Petrel	2
Cormorant to Red-faced Cormorant	3
Loon to Common Loon	1
Grebe to Horned Grebe	2
Duck to Common Eider	1
Gull to Mew Gull	2
Gull to Glaucous-winged Gull	5
Gull to Black-legged Kittiwake	6
Finch to Crossbill	1
TOTAL	64

3.7.3 Generalizing Identifications

Our identifications for 28 carcasses were more general than those listed in the log (table 3-5). One-half of these generalizations were instances where we could not be certain of the identity of a shearwater because the head was lacking. The remaining cases were divided among 11 types of generalizations.

3.8 Carcasses of Uncertain Status Regarding Oiling

It was not possible to ascertain whether some carcasses were from oiled or non-oiled birds. Carcasses of unknown oil status (table 3-7) were represented only by bones. Some had oiled bones, but we could not determine if the oil was a result of contact with other carcasses in the bag or if the oil was originally on the plumage of the bird. Many bones showed no trace of oil, but they still could have come from victims of the oil spill whose feathers and all traces of oil had been lost through scavenging or decomposition. The proportion of carcasses categorized as unknown ranged from 2 percent of the total for puffins to 16 percent for miscellaneous species and 14 percent for murres (table 3-7). Some carcasses with feathering had only small amounts of oil where they were in contact with other oiled carcasses in the bag. They may have become secondarily oiled after death through contact with other carcasses. The proportion of carcasses in this category were relatively low. They ranged from 1 percent for alcids (other than puffins) to 7 percent for gulls (table 3-7). The majority of oiled birds were completely coated with oil, leaving little doubt that they were oiled directly in the spill. We excluded all carcasses of birds that we considered to have been only possibly oiled or to have been of unknown oil condition (table 3-7) from all calculations on oiling rates.

TABLE 3-7. Number (n) and percent (%) of samples with no visibly oiled plumage (not oiled), with visibly oiled plumage (oiled), with visible oil that was possibly from other carcasses in bags (possibly oiled), and for which only skeletons remained (unknown oil condition). Other Alcids category excludes murres, puffins, or any carcasses that could have been murres or puffins. Other Swimmers category includes loons, grebes, cormorants, and ducks. Other Species includes mainly passerines, shorebirds, raptors, and galliforms.

	TOTAL	NOT OILED		OILED		POSSIBLY OILED		UNKNOWN OIL CONDITION	
		N	(%)	N	(%)	N	(%)	N	(%)
Tubenoses	641	486	(76)	127	(20)	18	(3)	10	(2)
Gulls	328	230	(70)	55	(17)	24	(7)	19	(6)
Murres	1788	41	(2)	1489	(83)	10	(1)	248	(14)
Puffins	119	97	(82)	13	(11)	7	(6)	2	(2)
Other Alcids	192	47	(24)	131	(68)	2	(1)	12	(6)
Other Swimmers	87	24	(28)	53	(61)	2	(2)	8	(9)
Other Species	88	41	(47)	28	(32)	5	(6)	14	(16)

3.9 Proportions of Oiled Carcasses

As Piatt et al. (1990) had hypothesized, the proportion of oiled birds in the sample changed over time. To look at the pattern of change, we divided the carcasses into seven groups: murres, puffins, other alcids, tubenoses, gulls, other swimming aquatic birds, and all other remaining species. We categorized the carcasses by time periods using the median collection dates for the birds in each bag or the date the birds were logged into freezer vans when no other date was available. Some birds were logged into the freezer vans within 1 or 2 days after being collected whereas others remained on the collecting vessels for 1 week or more. Consequently, we preferred to use collection dates over log-in dates when possible.

From early May through 10 July, nearly 100 percent of the murres had heavily oiled plumage (figure 3-1, top). However, we had to categorize a substantial number of murres as questionable with regard to oiling primarily because they were represented only by bones (figure 3-1, bottom). As mentioned previously, birds of questionable oiling status were always excluded from the calculations of the percentage of oiled birds. The percentage of oiled murres dropped somewhat in mid-July and declined slowly until early August. However, even during this declining phase, more than 70 percent of the carcasses were consistently oiled. Low sample sizes of murres prevented us from extrapolating oiling patterns beyond early August.

Not many puffins (Tufted and Horned Puffins) were available for examining oiling rates in May. The two that were examined were both heavily oiled (figure 3-2). About 60 percent of the 12 puffins in the June sample were heavily oiled, but the number of carcasses available for examination was still small. Reasonable samples of puffins were available for July and August. During both months, less than 10 percent of the carcasses had oiled plumage.

The oiling rates for the other alcids (including auklets, murrelets, Pigeon Guillemots, and Rhinoceros Auklets) were high from early May through the end of June (figure 3-3). No carcasses were available for early July, and only one of five carcasses from mid-July was

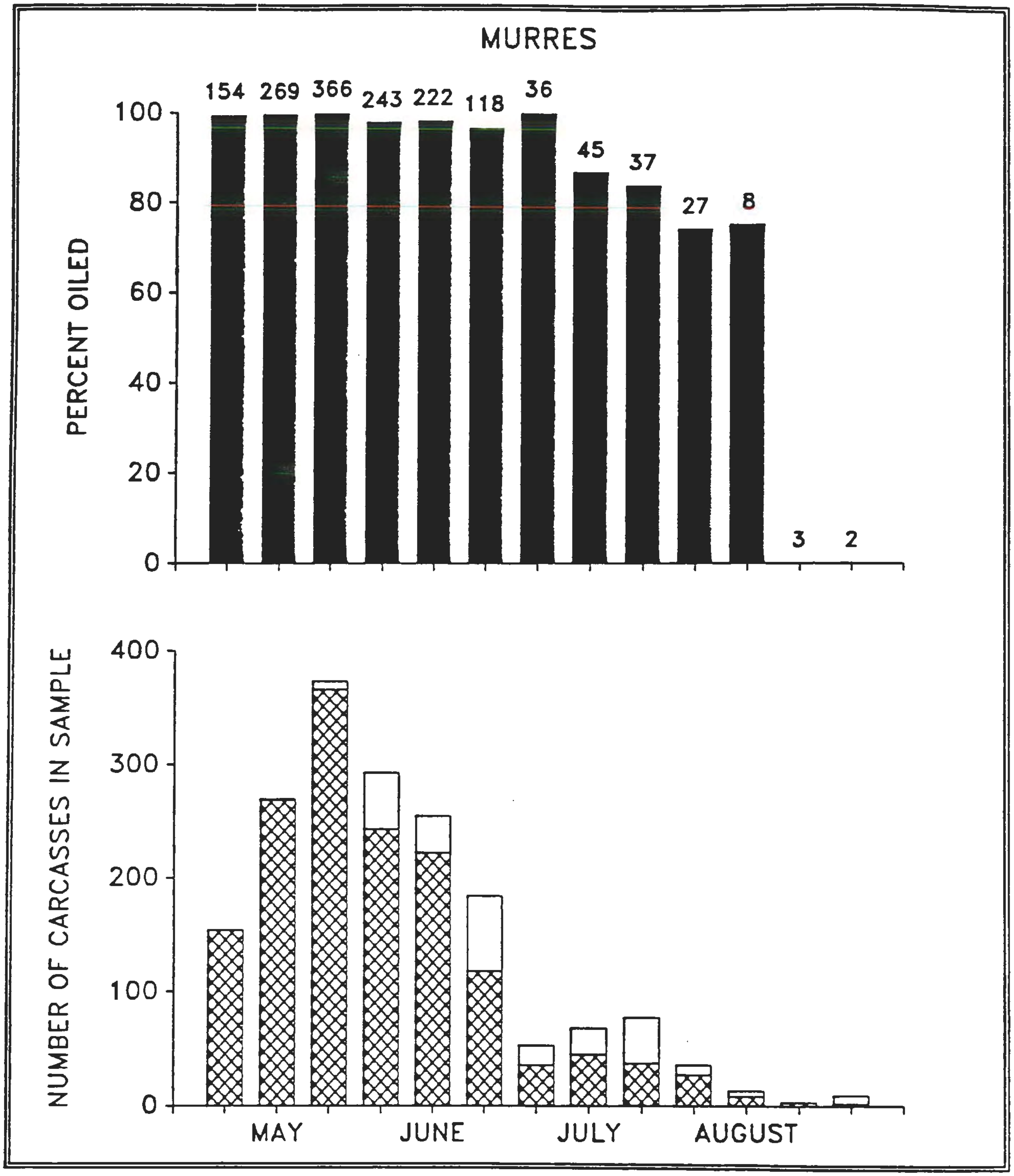


FIGURE 3-1. Number of carcasses (bottom) and percent of oiled carcasses (top) of murres during monthly periods. In the bottom graph cross-hatched bars indicate carcasses of known oil status, and open bars indicate carcasses of unknown or uncertain oil status. Calculations of the percentage of oiling are based only on carcasses of certain oil status; sample sizes are atop bars.

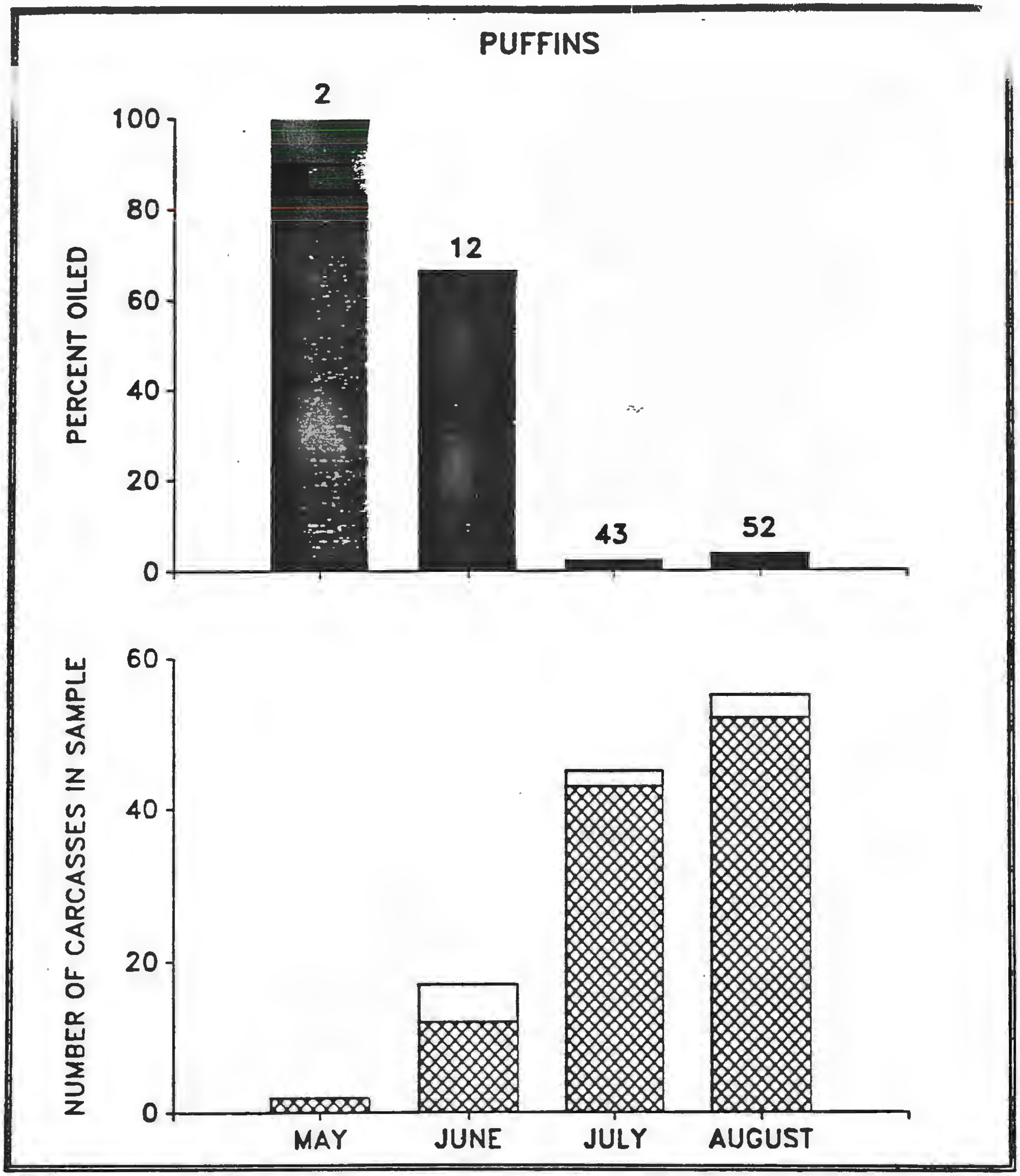


FIGURE 3-2. Number of carcasses (bottom) and percent of oiled carcasses (top) of puffins during monthly periods. In the bottom graph, cross-hatched bars indicate carcasses of known oil status, and open bars indicate carcasses of unknown or uncertain oil status. Calculations of the percentage of oiling are based only on carcasses of certain oil status; sample sizes are atop bars.

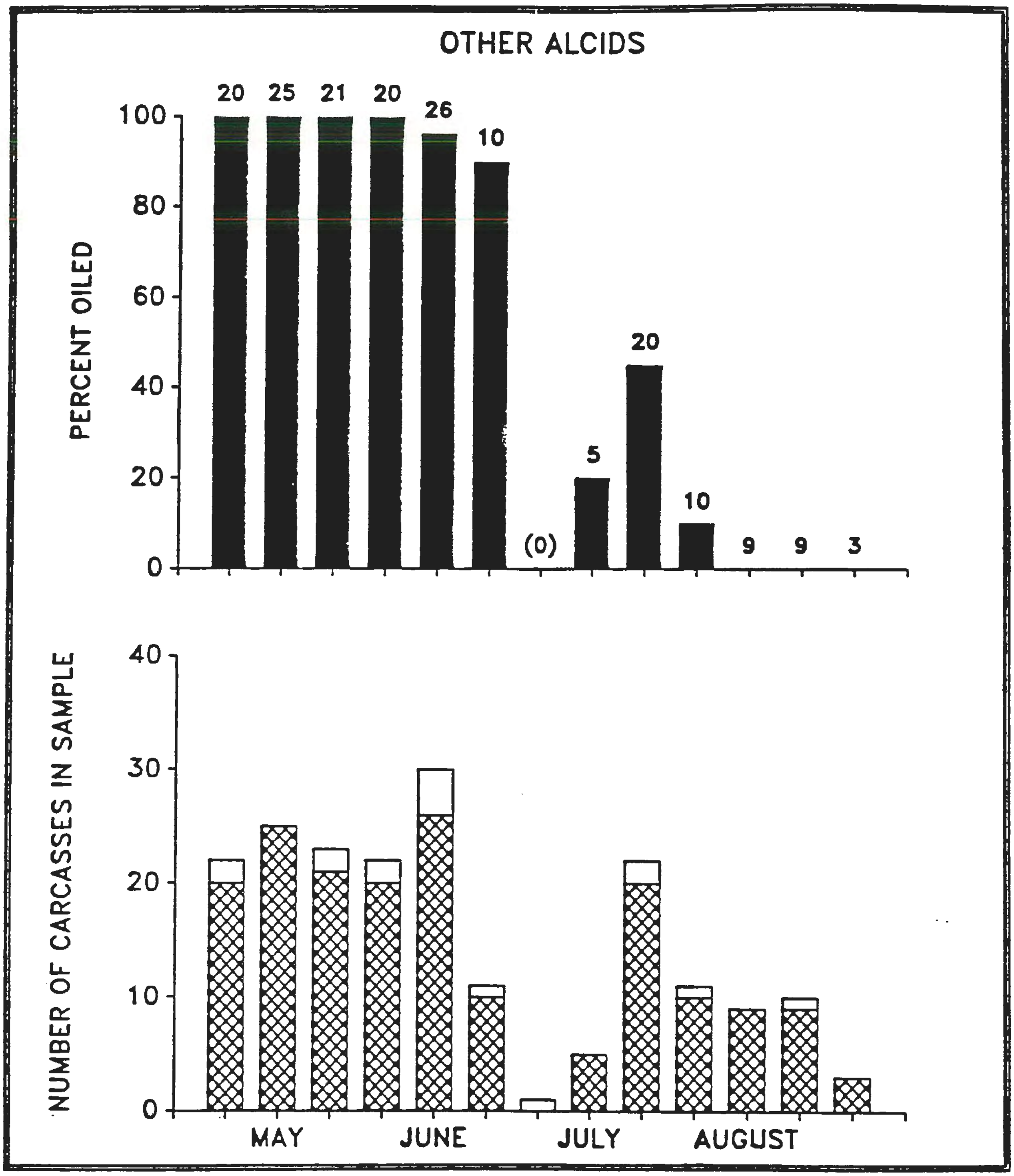


FIGURE 3-3. Number of carcasses (bottom) and percent of oiled carcasses (top) of alcids other than murres and puffins during monthly periods. In the bottom graph, cross-hatched bars indicate carcasses of known oil status, and open bars indicate carcasses of unknown or uncertain oil status. Calculations of the percentage of oiling are based only on carcasses of certain oil status; sample sizes are atop bars.

oiled. The late July sample was comparable in size to the May and June samples; 9 of the 20 carcasses from late July were oiled. Only 1 of 10 carcasses from early August was oiled. None of the 21 carcasses from after early August were oiled.

High oiling rates were apparent for tubenoses (fulmars, shearwaters, and storm-petrels) from mid May until early June (figure 3-4). Oiling rates declined moderately in June and sharply between late June and early July. Only about 15 percent of the tubenoses in early July were oiled. After early July the oiling rate for tubenoses was always less than 10 percent (figure 3-4).

The sample sizes available for examining oiling rates in gulls (primarily Black-legged Kittiwakes, Glaucous-winged Gulls and Mew Gulls) were low through May and June (figure 3-5). All 19 carcasses available for the period from early May to early June were oiled. Nearly 60 percent of the 14 carcasses from the remainder of June were oiled. Less than 20 percent of the substantial number of carcasses from July were oiled, and the oiling rate for August was practically zero.

Oiling rates for the remaining swimming aquatic birds (cormorants, grebes, ducks, and loons) declined steadily from May through August (figure 3-6). Although nearly 100 percent of the May carcasses were oiled, the oiling rate fell to under 70 percent in June and to about 40 percent in July. None of the eight carcasses from August were oiled.

The remaining species are represented by a broad mix of birds including shorebirds, passerines, raptors, and galliformes. The oiling rate for these birds compared fairly closely to that of the swimming aquatic birds (compare figures 3-6 and 3-7).

Our examination of the carcasses supports the hypothesis of Piatt et al. (1990) regarding the inclusion in the sample of birds that died of natural causes. However, the rate and timing at which these birds entered the sample is more accurately defined by our graphs of oiling

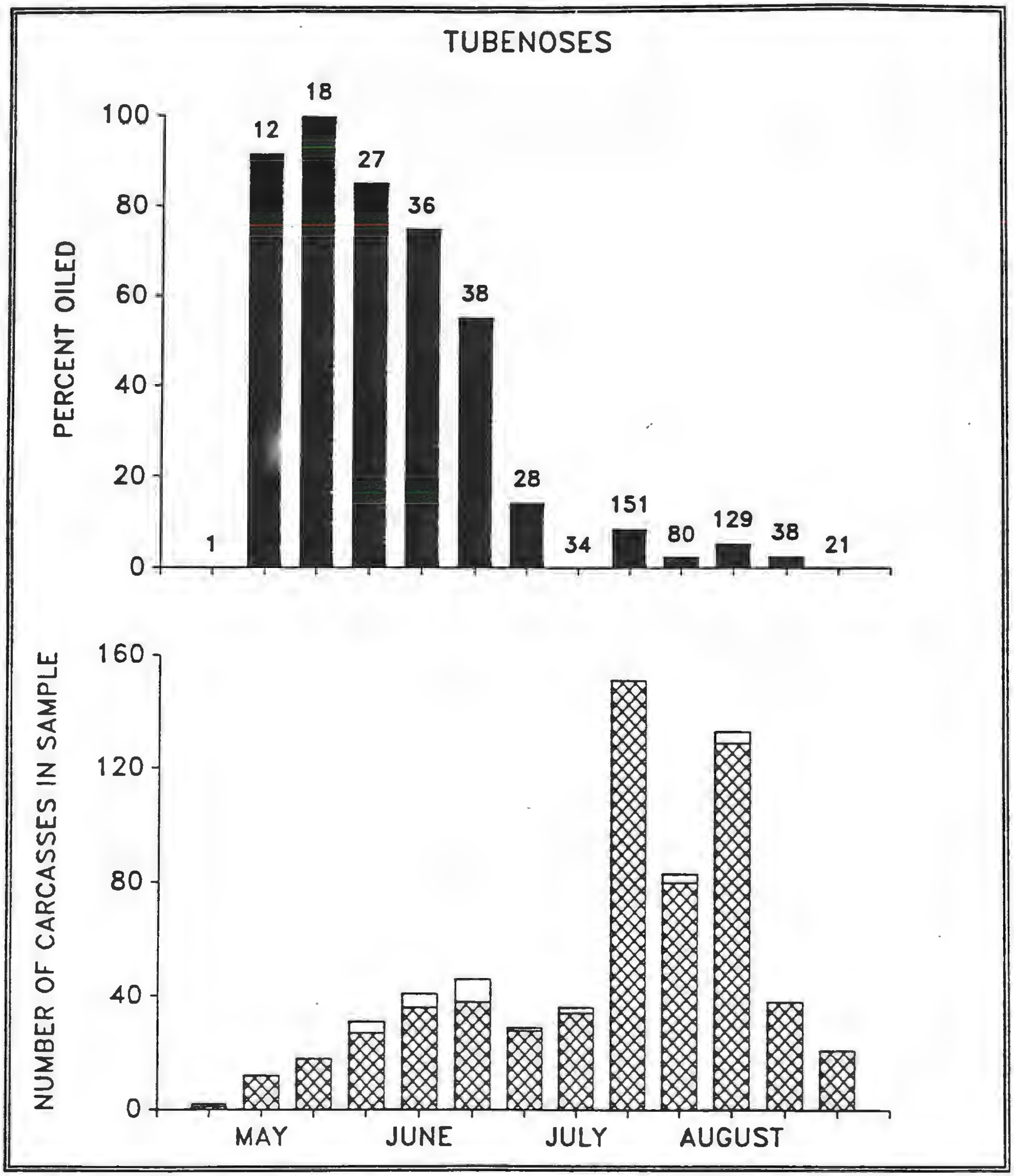


FIGURE 3-4. Number of carcasses (bottom) and percent of oiled carcasses (top) of tubenoses during monthly periods. In the bottom graph cross-hatched bars indicate carcasses of known oil status, and open bars indicate carcasses of unknown or uncertain oil status. Calculations of the percentage of oiling are based only on carcasses of certain oil status; sample sizes are atop bars.

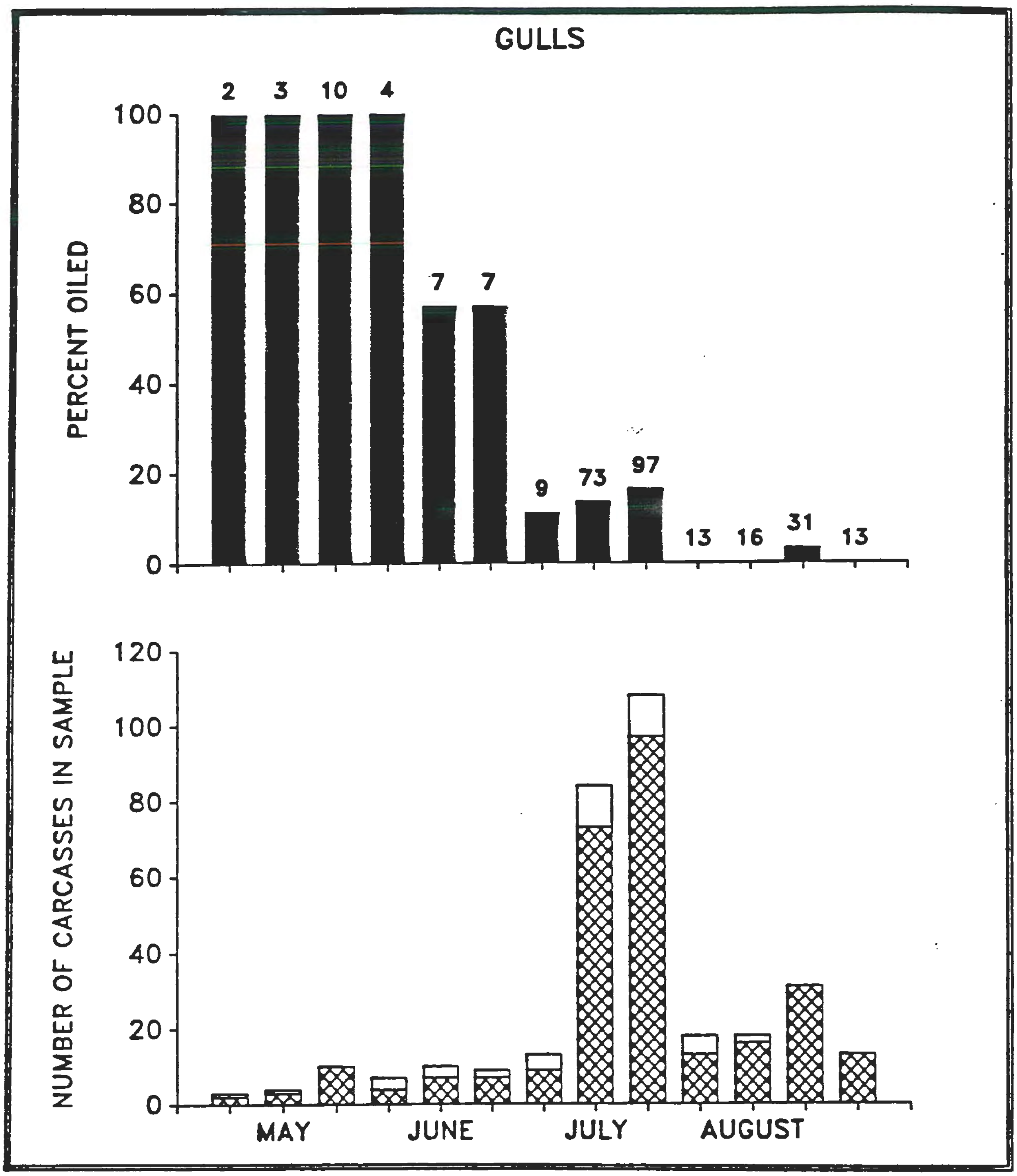


FIGURE 3-5. Number of carcasses (bottom) and percent of oiled carcasses (top) of gulls during monthly periods. In the bottom graph cross-hatched bars indicate carcasses of known oil status, and open bars indicate carcasses of unknown or uncertain oil status. Calculations of the percentage of oiling are based only on carcasses of certain oil status; samples sizes are atop bars.

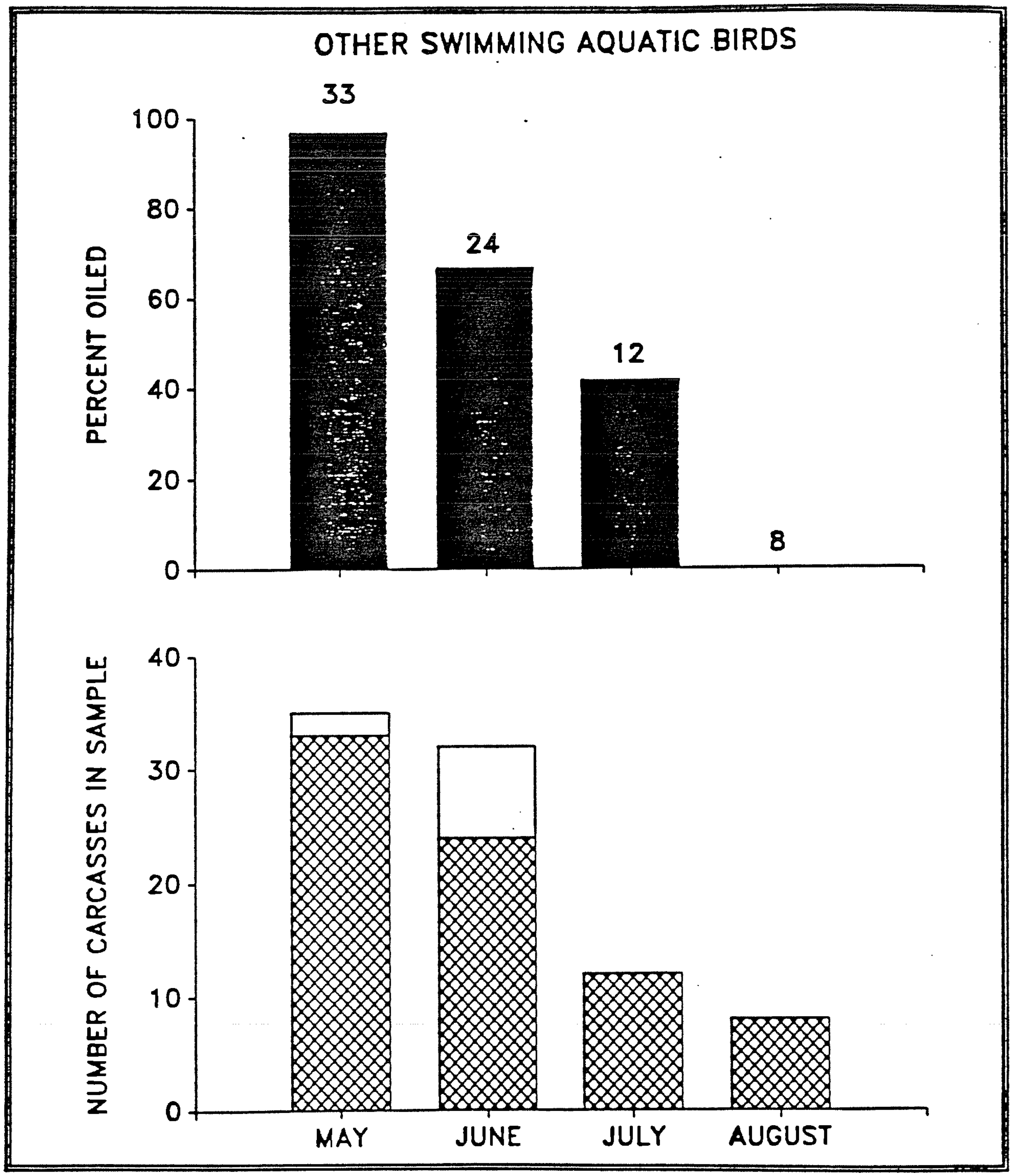


FIGURE 3-6. Number of carcasses (bottom) and percent of oiled carcasses (top) of cormorants, ducks, grebes, and loons during monthly periods. In the bottom graph cross-hatched bars indicate carcasses of known oil status, and open bars indicate carcasses of unknown or uncertain oil status. Calculations of the percentage of oiling are based only on carcasses of certain oil status; sample sizes are atop bars.

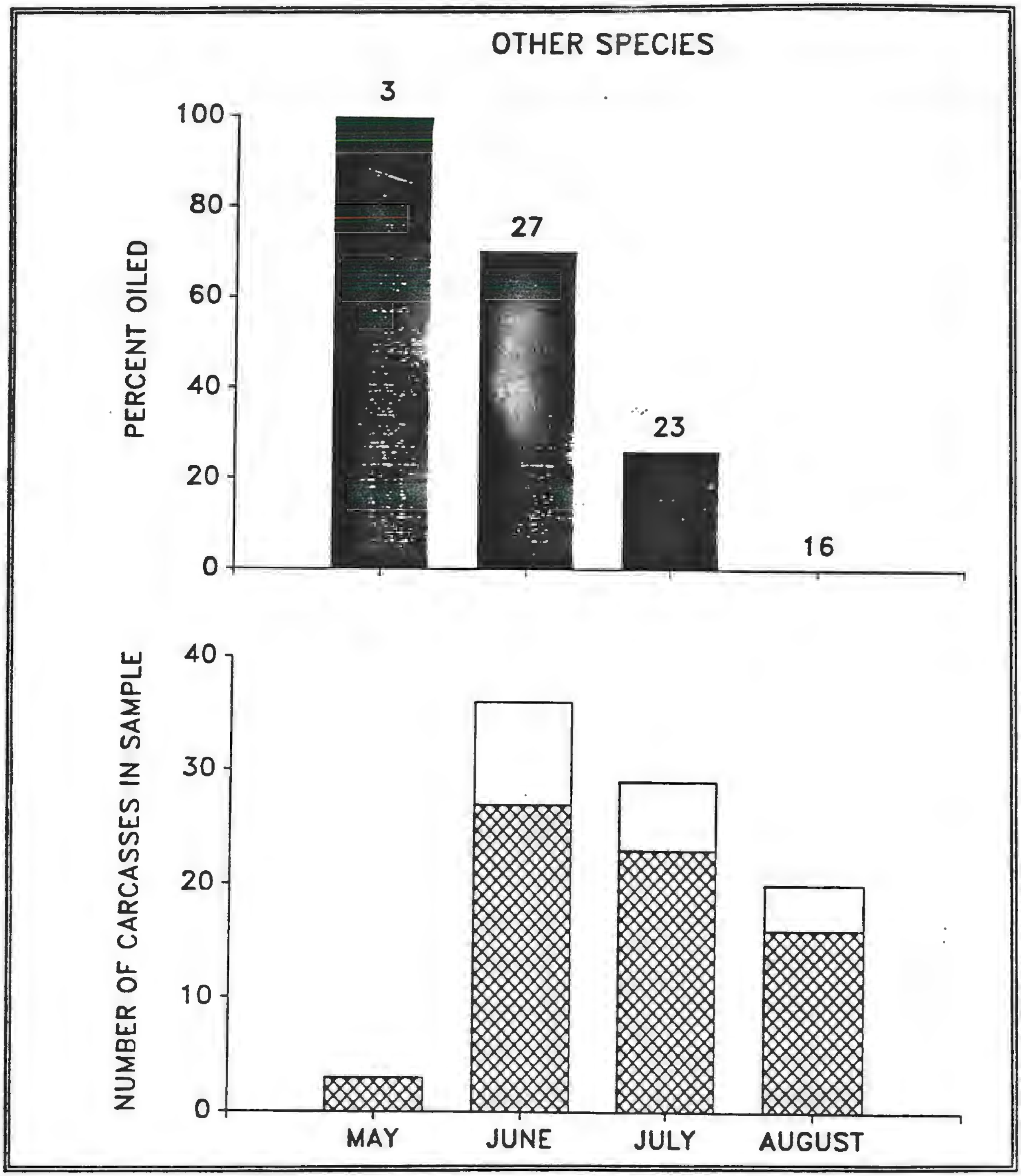


FIGURE 3-7. Number of carcasses (bottom) and percent of oiled carcasses (top) of shorebirds, raptors, passerines, and galliformes during monthly periods. In the bottom graph cross-hatched bars indicate carcasses of known oil status, and open bars indicate carcasses of unknown or uncertain oil status. Calculations of the percentage of oiling are based only on carcasses of certain oil status; sample sizes are atop bars.

rates than by the 31 July cutoff point of Piatt et al. (1990). The timing and rate at which unoiled birds entered the sample differ among broad taxonomic groups. High oiling rates persisted longer for murres than for any other group. Apparently most of the puffins and gulls in the sample appeared late in the spill period and did not have oiled plumage. Piatt et al. (1990) hypothesized that these two taxonomic groups were suffering from late-season natural dieoffs. For tubenoses, the other group with a hypothesized natural dieoff, the oiling pattern fell intermediately between that of the murres and those of the gulls and puffins. Oiling rates for tubenoses, while high early in the spill period, had declined sharply by early July rather than at the 31 July cutoff point used by Piatt et al. (1990). The patterns for other birds were difficult to determine because of low sample sizes.

3.10 Conclusion

Our examination of a sample of carcasses from the Kodiak-Alaska Peninsula vans provided an opportunity to improve the level of carcass identification and to ascertain the relative proportions of oiled and unoiled birds in the sample. Only about 2.5 percent of the carcasses had been incorrectly identified. Another 11 percent of the carcasses could have been identified more precisely than was reported. However, reconciling the number of carcasses logged into the morgues precisely with the numbers of carcasses in the bags is not possible because carcass parts from several locations or time periods were placed together in bags after being recorded in the morgue log. Up to 7 percent of the carcasses of some groups of birds could be classified only as "possibly oiled" because the small amount of oil on their plumage could have been derived secondarily from contact with other oiled birds in the bags. Up to 16 percent of some species groups could not be classified regarding oiling because the carcasses consisted only of bones. Temporal patterns of oiling supported the contention that natural deaths of some species of birds occurred during the latter part of the spill period. Temporal patterns of oiling varied among species groups. High oiling rates persisted longer for murres than for any other group. Most of the puffins and gulls in the sample appeared late in the spill period and did not have oiled plumage. The pattern for tubenoses fell intermediately between that of the murres and those of the gulls and puffins. Puffins, gulls, and tubenoses were the taxa believed to be experiencing natural dieoffs late in the spill period. The oiling patterns for other birds were difficult to determine because of low sample sizes.

4.0 EXTERNAL DATA SOURCES

Data from several sources were used to provide input for model calculations. Described below are the sources of data used to analyze the time course of oil movement, distribution of marine birds, and the characteristics of the affected shoreline.

4.1 Time Course of Oil Movement

The number of seabird carcasses that are lost before being beached depends on the length of time that the carcasses are at sea before reaching land. To calculate this number, an approximation of the time course and geographic extent of the oil slick is necessary. Information on the movement of the oil serves a dual purpose: (1) when overlaid with the distribution of birds, the rate at which birds encountered the slick can be approximated, and (2) by assuming that the oil and the bird carcasses move together, the time and location at which the carcasses would make landfall can be estimated. The data of Hope-Jones et al. (1970) generally supports the latter assumption, as well as the observation that during most oil spills, including the *Exxon Valdez*, incident birds and oil tended to come ashore together. The length of time spent drifting at sea and the rate of disappearance at sea can be used to generate estimates of the proportion of carcasses enroute to a particular stretch of coastline that were lost before landfall.

The best source of trajectory data for this type of analysis is the NOAA-HAZMAT-OSSM (Torgrimson, 1981). As output, this model estimates the position of a particle of oil (a Lagrangian element) at successive time intervals, forming an overall picture of the progression of the slick. The NOAA hindcast of the spill extends from the beginning of April to the beginning of May, after which time it was felt that the quantity of oil remaining and the available observations of the extent of the slick did not make it worthwhile to continue the simulation. To characterize oil movement during and after May, we used data from overflights that NOAA compiled and mapped as part of its response to the incident. Copies of these overflight maps were obtained from Bill Lehr (NOAA HAZMAT, Seattle).

Oil began flowing from the damaged *Exxon Valdez* at Bligh Reef on 24 March 1989. Pushed by northeast winds and the prevailing anticlockwise current flow in Prince William Sound, the slick moved south through Knight Island Passage and Montague Strait, coating the shorelines primarily along the western side of the Sound. By 29 March, oil entered the Gulf of Alaska and began moving to the southwest past Resurrection Bay and along the Kenai Peninsula. Data generated by the NOAA hindcast of the oil spill indicate that about 13 percent of the total spill volume, or about 33,000 barrels, entered the Gulf; the remainder of the oil ultimately evaporated or was beached within Prince William Sound. On 13 April, a U.S. Coast Guard overflight found sheen and mousse out to the tip of the Kenai Peninsula, in the vicinity of the Barren Islands, and as far south as the northern end of Shuyak Island. The hindcast shows that the main mass of the slick gyred for several days in the vicinity of the Barren Islands before moving up into Cook Inlet and down Shelikof Strait. A part of the slick began moving southward at this time, passing down Kodiak Island on the seaward side (figure 4-1). Based on the hindcast of the spill, less than 2 percent of the original volume of the oil remained floating by late April; however, given the original volume of the spill, this percentage still represented a substantial quantity of oil. The NOAA hindcast ends in May and does not model trajectories south of the northern end of Kodiak Island.

Based on NOAA overflight data, the leading edge of the Shelikof Strait portion of the slick proceeded southwest at about 10 km per day, reaching Sutwik Island on the Alaska Peninsula by 6 May (figure 4-2). Coast Guard and NOAA observers found no heavy concentrations of oil at this time but noted widespread sheen throughout the Strait. Oil proceeded more slowly along the eastern side of Afognak and Kodiak Islands, moving at a rate of about 4 km per day. Along this side of Kodiak, NOAA overflights did not reveal signs of oil south of about 58° N, somewhat north of the latitude of the town of Kodiak. The fact that large numbers of birds were recovered along the entire Shelikof side of Kodiak Island during April and May but not along the southeastern side indicates that the dead birds

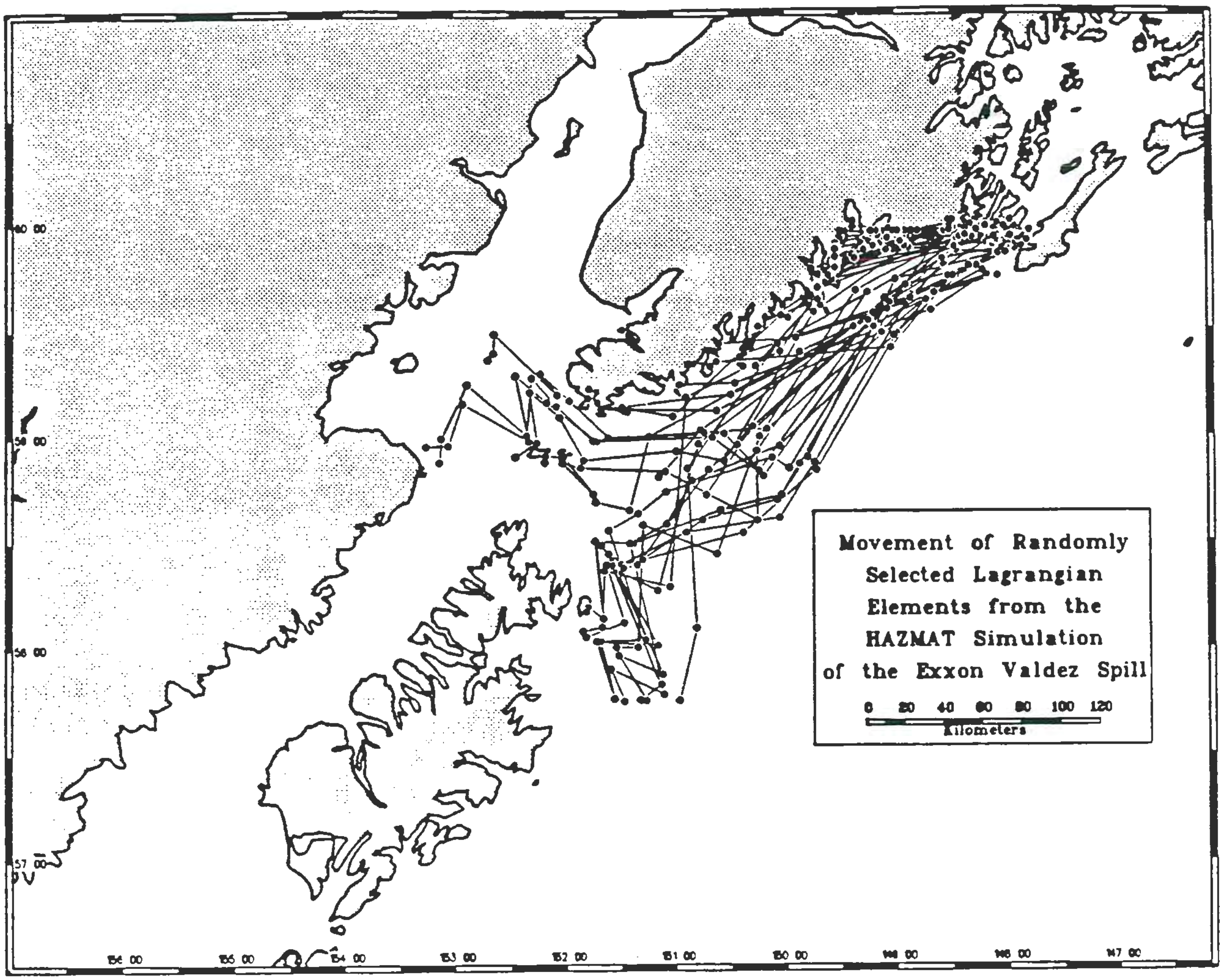


FIGURE 4-1. The movement of Lagrangian elements simulated by the NOAA/HAZMAT On-Scene Spill Model for April 1989. The movement of these elements provides a way of simulating where and when seabirds would have encountered the oil slick and how long carcasses would have drifted. For clarity, this map contains a randomly selected subset of the Lagrangian elements simulated by the model. Lines connect the positions of each element at 3-day intervals; the model actually resolves down to 3-hour intervals. Circles denote the position at each 3-day interval.

recovered in the Trinity Islands just south of Kodiak originated on the Shelikof side of the Strait.

In spite of the fact that the slick became difficult to trace as it moved southward, dead birds continued to come ashore along both sides of Kodiak Island and the Alaska Peninsula as

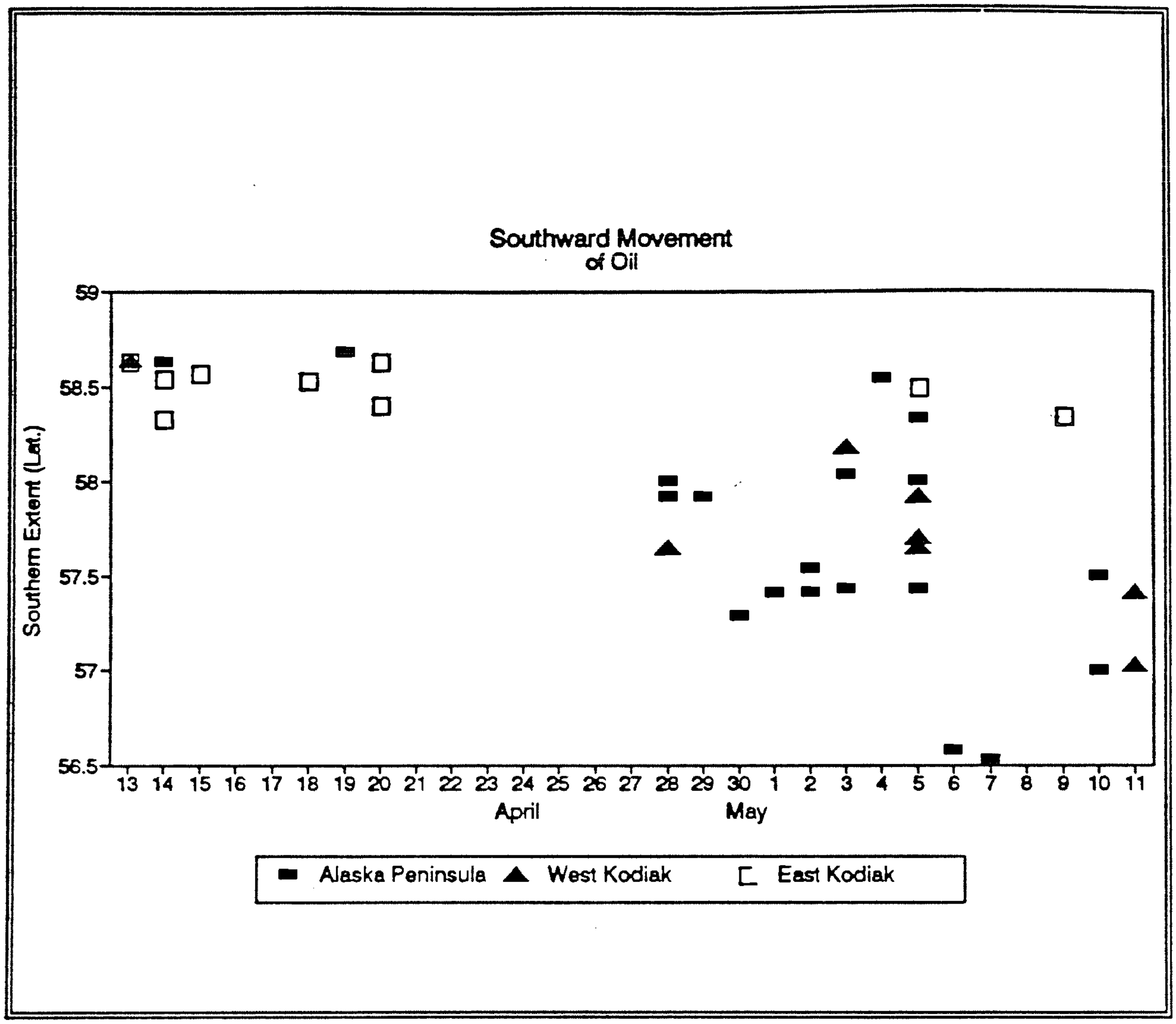


FIGURE 4-2. Southward movement of oil.

far south as Perryville, more than 200 km southeast of Kodiak Island. Morgue records show that birds were logged in through September, but shifts in species composition and a decline in the frequency of oiling of the dead birds suggest that, at some point, oil-induced mortality dropped off and natural mortality became the primary source of dead birds. Interpretation of the timing of the arrival of beached birds is complicated by the time lag between when the birds were logged in at the morgues and when they actually arrived onshore. Nonetheless, it is clear that oiled birds continued to arrive for months after the leading edge of the slick had passed. Our examination of murre carcasses from Kodiak Island and the Alaska Peninsula (see section 3) showed that about 70 percent of the beached murres were oiled as late as the beginning of August. Carcass drift data from the Kodiak area during July and August of 1990 also showed that the likelihood of a carcass persisting in these waters for more than 3 weeks is very low, implying that actual mortality must have continued at least well into June to account for birds recovered during August. It is impossible to model trajectories during this latter part of the spill, when the oil had become very difficult to see and had already affected most of the shoreline that would be affected. It is likely that some of the late-summer mortality resulted from numerous light slicks, some of them probably originating from rewash, which remained in the area at this time. It is also possible that some of the carcasses recovered later in the year were burials that were later uncovered.

Bird carcasses began coming ashore soon after the spill began, and beachings continued for several months. As the oil moved out of Prince William Sound and moved southward through the Gulf of Alaska, bird carcasses were spread over a larger and larger area. Numbers peaked in May, but murre carcasses were arriving at processing centers well into September. Figure 4-3 illustrates this progression for murre carcasses. Processing dates were used in creating these figures. Beaching dates would be somewhat earlier, because of the time lags between beaching and collection, and between collection and processing.

4.2 Distribution of Marine Birds

4.2.1 Introduction

As the slick moved through Prince William Sound and south along the western margin of the Gulf of Alaska, thousands of marine birds came into contact with the oil. The abundance of each species, which varies within the affected area, in part determines the composition of the population of beachcast birds. Differences in proportions of species of beachcast birds from place to place was discussed by Piatt et al. (1990), who noted that the species composition of beachcast birds was often different from that of the local seabird fauna. This difference was attributed to differences in the vulnerability of species and the

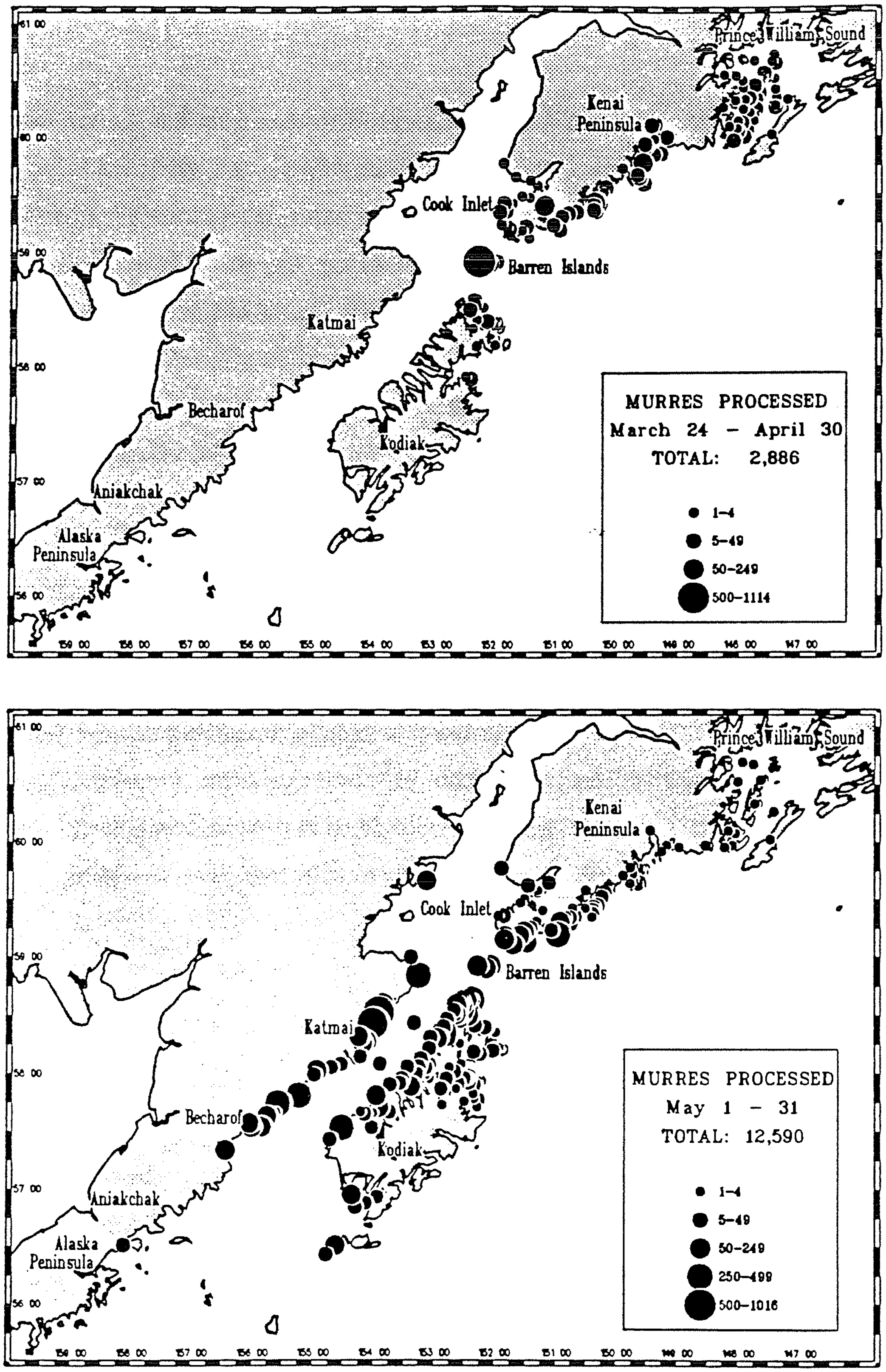
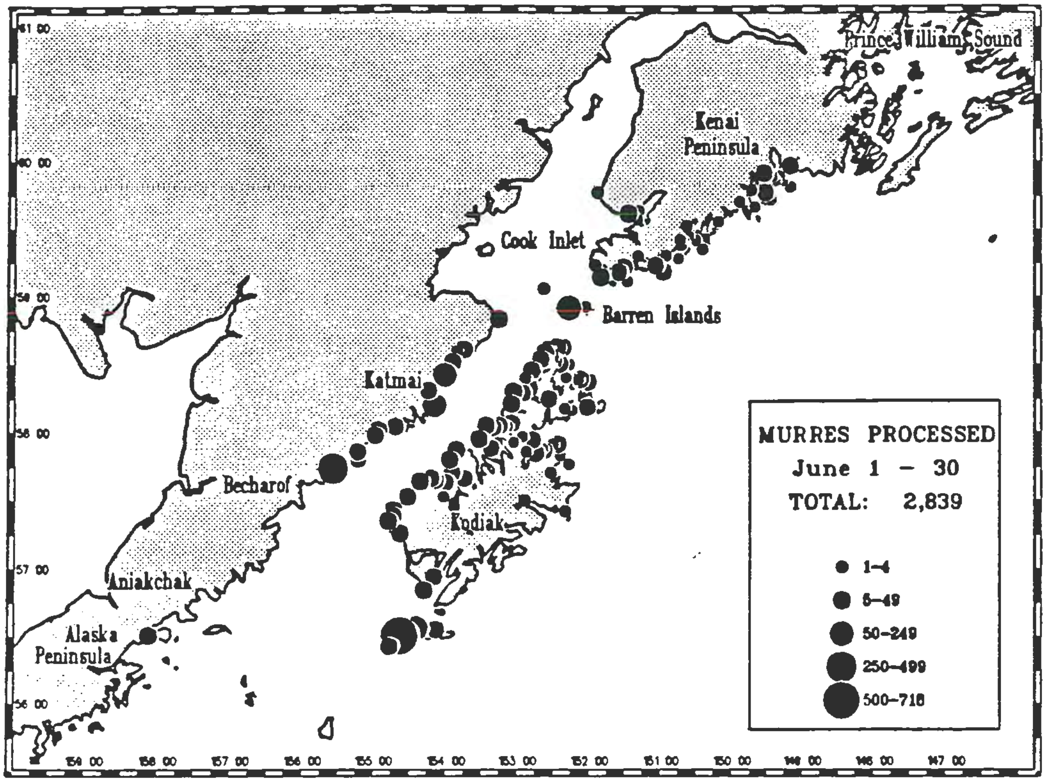


FIGURE 4-3. Reported collection locations of murre carcasses processed during sequential time intervals. This figure illustrates the change in pattern and magnitude of bird beachings though time.



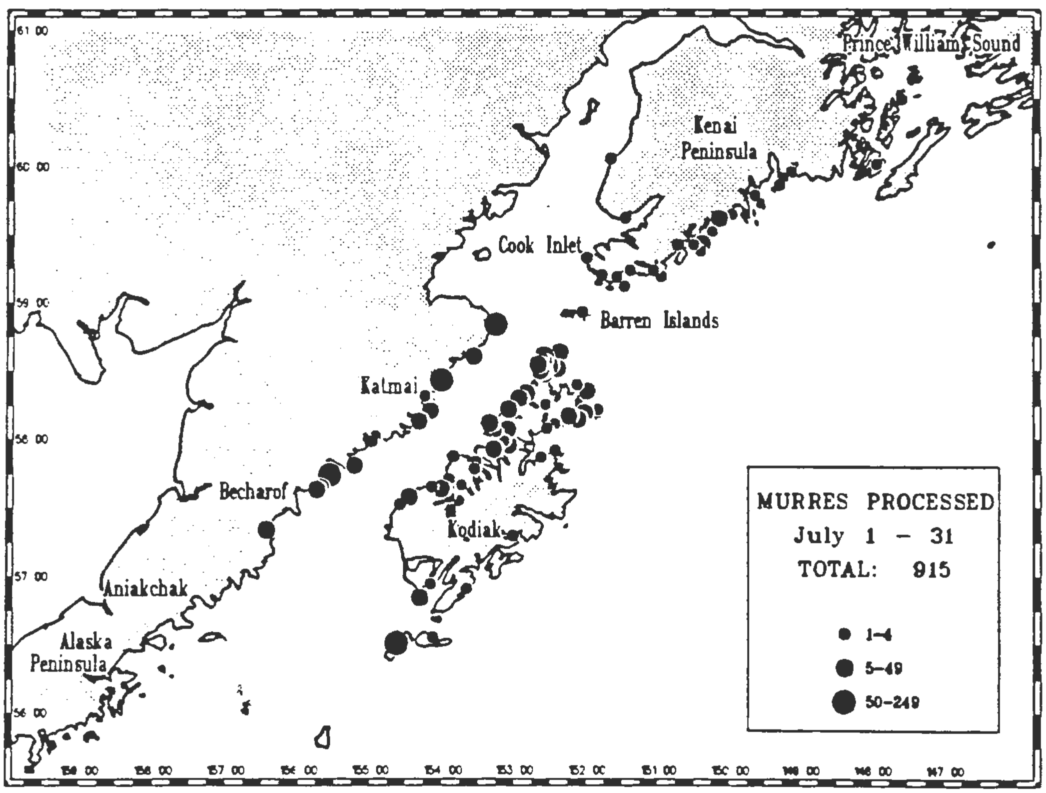
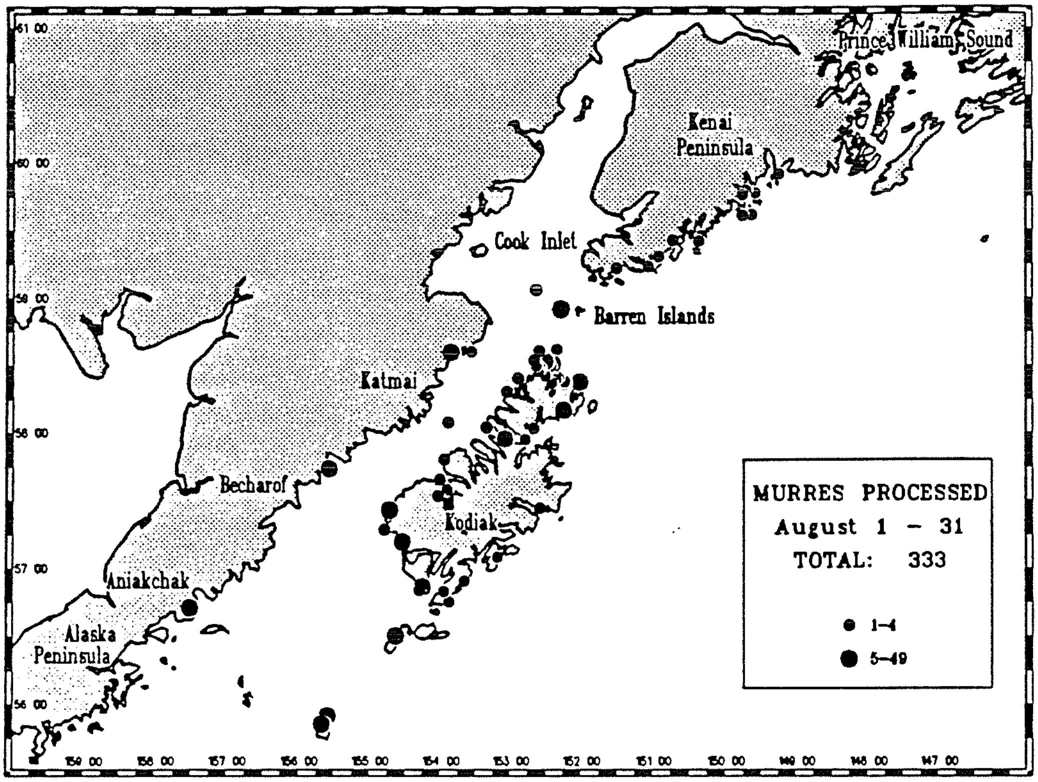


FIGURE 4-3. (Cont'd.)



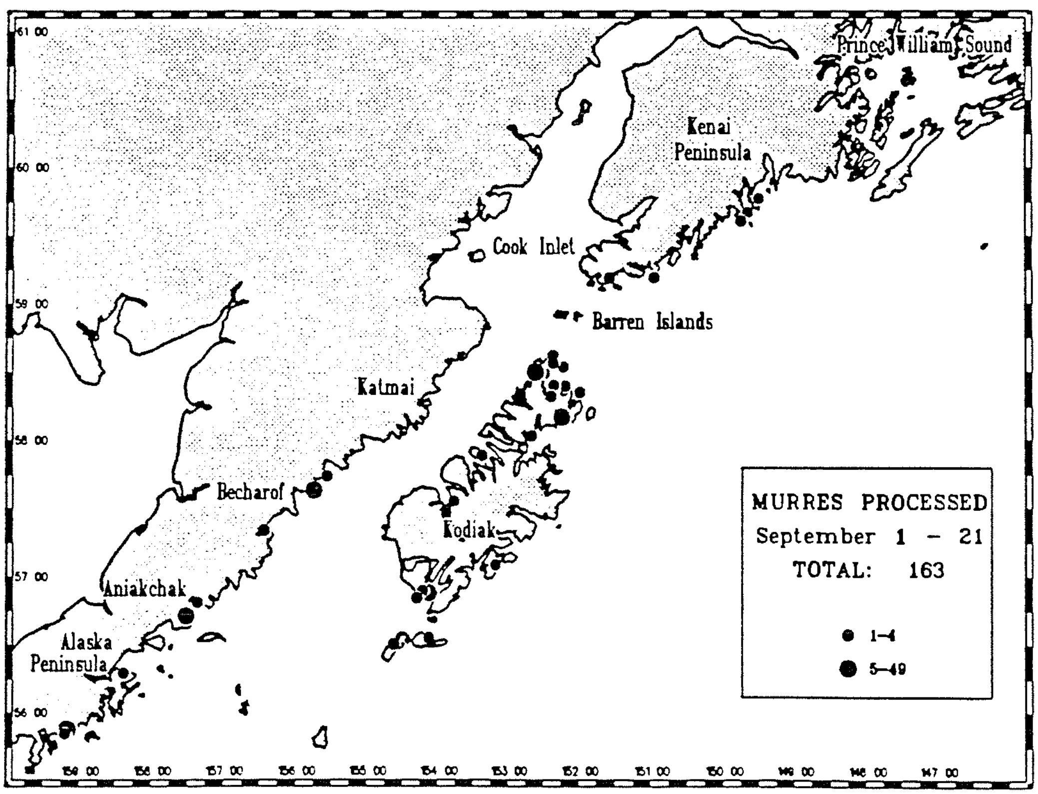


FIGURE 4-3. (Cont'd.)

fact that many birds probably drifted substantial distances. Species that have the greatest representation among collected oiled birds include alcids, sea ducks, cormorants, loons, and grebes. These birds are especially vulnerable because they spend much time on the surface and form large flocks. Because of their high local densities and vulnerability to oil, Common Murres were the most frequently recovered species. Gulls and procellariids, while often very abundant, account for only a small proportion of collected oiled birds. Once oiled, birds apparently drifted with the oil mass until beaching. During this time, some carcasses were lost due to sinking and/or scavenging. Given both the length of time that the carcasses were found to have floated in Prince William Sound and the tendency of both oil and bird carcasses to beach within the Sound, it is likely that most birds oiled in the confines of Prince William Sound beached before they had time to sink. In other parts of the affected area, dead birds were probably carried substantial distances before being beached. Because sinking is a function of time (section 5.1), carcasses that were at sea for longer periods of time were more likely to be lost; these carcasses therefore are underrepresented among beachcast birds collected after the spill.

To estimate total mortality from beachcast carcasses, numbers of birds lost at sea must be considered. Knowing the location of concentrations of birds of various species relative to the course of the oil movement helps in determining how long carcasses found on a given beach were floating before coming ashore. This information, in turn, provides a means for estimating how much loss occurred along the way.

To estimate the number of birds, we used density distributions of three groups of birds: (1) murres, (2) small alcids (auklets and murrelets), and (3) sea ducks, cormorants, loons, and grebes (combined). These marine bird species are the most vulnerable to oil spills and are most commonly represented among oiled birds collected on the beach. For modeling purposes, we used 30′ blocks of latitude and longitude for the periods April through May and June through July. Distributions were mapped using effort-corrected observations recorded during OCSEAP and USFWS surveys and archived in the National Oceanographic Data

Center (NODC) data base maintained by the University of Rhode Island.[1] The path and progress of the oil slick through these density fields were simulated using the HAZMAT model discussed in section 4.1.

4.2.2 Overview of Marine Bird Fauna

Piatt et al. (1990) reviewed available information on numbers and species composition for waters affected by the spill. From boat surveys, the spring population of birds in Prince William Sound at any point in time numbers 300,000 to 400,000 consisting predominantly of the following species: 37.2 percent sea ducks, 25.2 percent gulls, 6.4 percent cormorants, 6.3 percent murrelets, 3.3 percent grebes, 1.8 percent murres, 1.4 percent loons, and 1.2 percent guillemots (Dwyer et al., 1975; Irons et al., 1988). Along the southeastern Kenai Peninsula, more than 36,000 birds were counted on a pre-contact aerial survey. In coastal waters of the Kenai, sea ducks accounted for 42 percent and murres for 34 percent of the total birds. Gulls (22 percent) and cormorants (6 percent) were also abundant in coastal waters. Offshore, the predominant species were murres (19.5 percent), procellariids (13 percent), gulls (15 percent), and phalaropes (11 percent). Puffins, which accounted for 17 percent or more of the birds

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[1]NODC digital data used in the seabird synthesis data base includes:

Divoky, G. The distribution, abundance and feeding ecology of birds associated with pack ice. 1976-1978, BLM/OCSEAP.

Guzman, J. Ecology and behavior of southern hemisphere shearwaters over the OCS of the Bering Sea and Gulf of Alaska during the northern summer. 1975-1976, BLM/OCSEAP.

Hunt, G.L., Jr. Reproductive ecology, food, and foraging areas of seabirds nesting on the Pribilof Islands; various other projects. 1975-1983, BLM/OCSEAP; NOAA/OMPA.

Weins, J.A. Community structure, distribution, and interrelationships of marine birds in the Gulf of Alaska. 1975-1976, BLM/OCSEAP.

USFWS. Seasonal distribution and abundance of marine birds in Alaskan waters; other projects. 1975-1986, BLM/OCSEAP.

found offshore later in the spring, had not yet arrived in the area in large numbers at the time of the spill. Sowls et al. (1978) estimate that about 116,000 seabirds are found at colony sites along the southeastern Kenai in the summer. Common Murres have major colonies totaling more than 28,000 birds at sites near Resurrection Bay and Chiswell Island (USFWS colony data base). For the southwestern Kenai coast, precontact aerial surveys showed that at least 21,000 ducks, gulls, and murres, and more than 123,000 birds were present on or near the Barren Islands (79 percent of these were murres, and 20 percent were gulls). USFWS colony data indicate that 150,000 Fork-tailed Storm-Petrels, 135,400 puffins, 118,000 Common Murres, 11,500 Thick-billed Murres, and 46,600 kittiwakes breed on the Barren Islands. On a ship survey following the path of the oil, Piatt (1989) found densities of 14.6 birds/km^2 in Shelikof Strait and 28.4 birds/km^2 along the Alaska Peninsula. Density of 65.4 birds/km^2 was found near the Semidi Islands. Murres were the most abundant at sea (65 percent of all observations), followed by procellariids (15.4 percent) and gulls (4.4 percent). The total population in Shelikof Strait is estimated at about 295,000 birds. Populations of murres on the Semidi Islands total about 1.133 million birds (USFWS colony data base). Sowls et al. (1978) estimate populations at colonies along the Alaska Peninsula to total 308,000 birds and colonies on Afognak Island to total about 39,000 birds. Predominant colonial species include murres, puffins, gulls, and kittiwakes. More recent counts indicate that populations of murres on the Alaska Peninsula total about 340,000 birds; the largest colonies are located near Cape Kekurnoi, Atkulik Island, Spitz Island, and Karpa Island (USFWS colony data base). Several hundred thousand sea ducks are also present in coastal waters of Kodiak and Afognak Islands and the Alaska Peninsula (Forsell and Gould, 1981).

4.2.3 Pelagic Distribution from OCSEAP/USFWS Survey Data

4.2.3.1 Murres

Both Common Murres and Thick-billed Murres are found in waters of the western Gulf of Alaska. Common Murres have an Alaska nesting population of about 5 million birds, with the largest colonies located in Bristol Bay, the eastern Aleutians, the Shumagins, Kodiak

Island, and the Kenai Peninsula (Sowls et al., 1978). Gould et al. (1982) and OCSEAP ship surveys in the winter found Common Murres only near Kodiak Island. In the spring, numbers increase dramatically, and Common Murres become abundant throughout the western Gulf of Alaska. The distribution at sea is mostly confined to shelf waters (< 200 m depth); beyond the shelf break, numbers decline to low density (< 5 birds/km^2). Thick-billed Murres are also present in the western Gulf of Alaska, but the center of their nesting abundance is the Bering Sea. They reach their greatest numbers in the western Gulf of Alaska from November through March. During the spring, they are most numerous near the Shumagin Islands. In spring, Common Murres may outnumber Thick-billed Murres in the Gulf of Alaska by a factor of 5. OCSEAP and USFWS surveys show that murre density in Prince William Sound is low in the spring (< 5 birds/km^2), while somewhat greater numbers are found 30 to 50 km west of Middleton Island. Along the Kenai, high densities (20 to 25 birds/km^2) are found in Blying Sound and moderate to high densities (10-25 birds/km^2) are found in the vicinity of Resurrection Bay, Aialik Bay, and Harris Bay. Low-moderate and moderate densities (5 to 15 birds/km^2) are present near the Barren Islands and in lower Cook Inlet, increasing to high-moderate densities (15 to 20 birds/km^2) 20 to 40 km east of Afognak Island over Portlock Bank. From Kodiak southwest to Chirikof and Semidi Islands, murre densities are moderate to high. Densities tend to be low to moderate in the Shelikof Strait. Very high densities (up to 111 birds/km^2) have been recorded in coastal waters of the Alaska Peninsula off Chignik Bay, Castle Cape, and the vicinity of Mitrofania Island. The distribution of murres in April and May is shown in figure 4-4.

A similar pattern occurs in the summer, although the population is lower than in the spring. In June and July, low to low-moderate densities (< 10 birds/km^2) are found throughout shelf waters off the Kenai Peninsula, around the Barrens, and in Shelikof Strait. Density of murres in coastal waters of the Kenai Peninsula in summer is much reduced from spring levels. Moderate densities (5 to 15 birds/km^2) occur 30 to 50 km east of Afognak over Portlock Bank. In this same area in the spring, densities were substantially greater. High to very high densities have been recorded near the Semidi Islands and along the Alaska Peninsula from Chignik Bay to Mitrofania Island (figure 4-5).

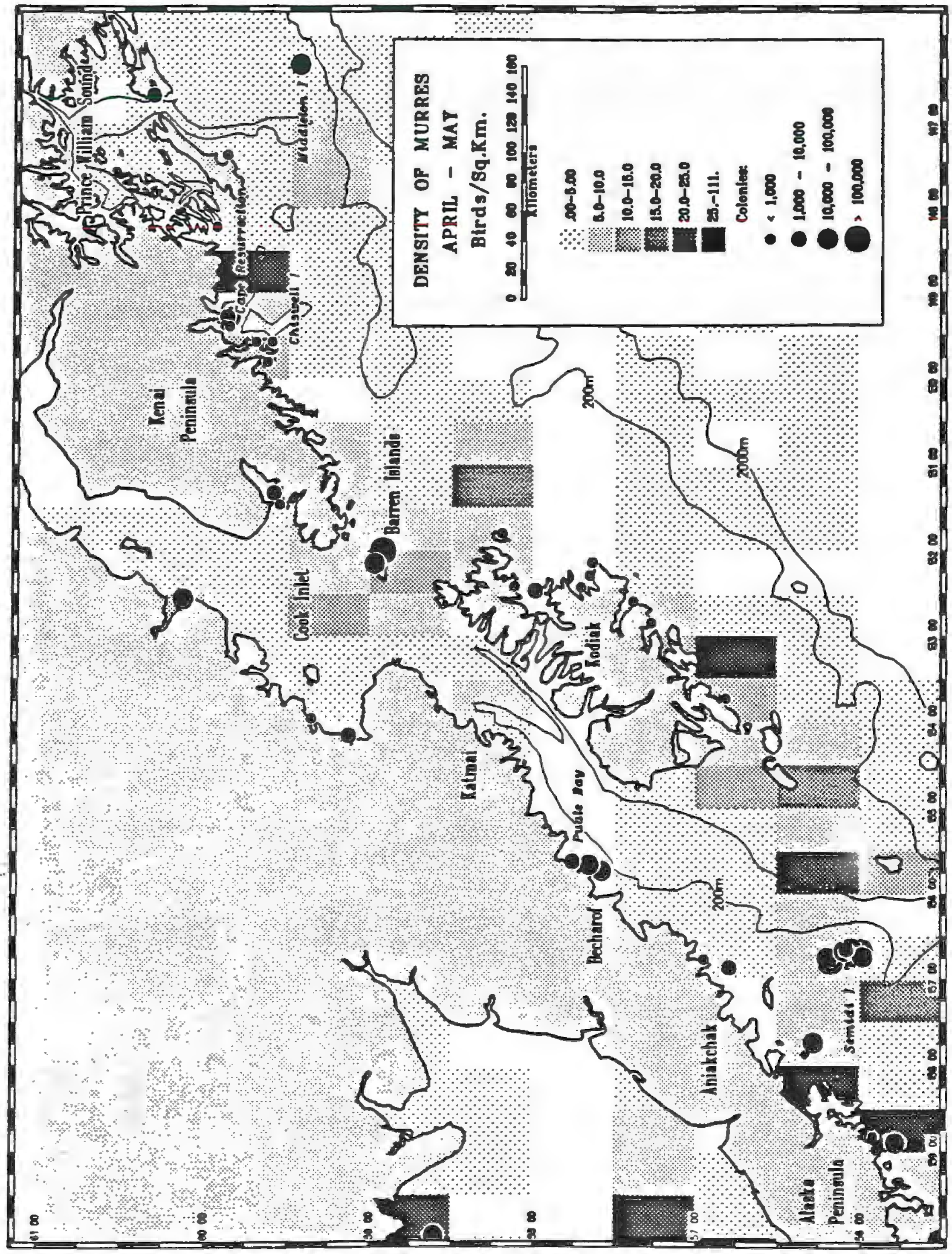


FIGURE 4-4. Distribution of all murres during April and May, based on the OCSEAP data base. Data are summarized into 30-minute blocks for display and analysis. Colonies are displayed as filled circles; the size of the circle is proportional to the size of the colonies. Colony data are from Sowls et al. (1978), supplemented by more recent counts where available.

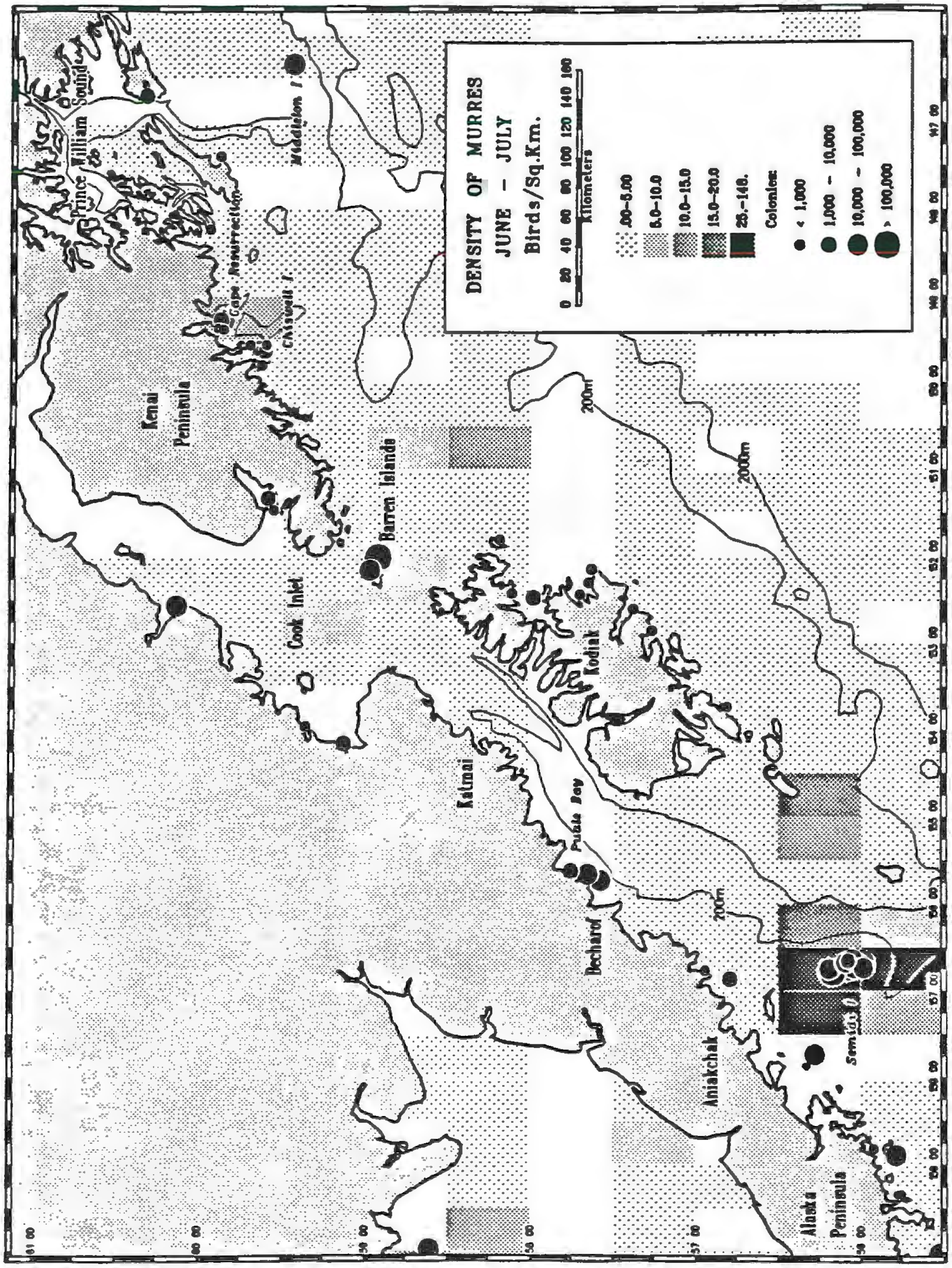


FIGURE 4-5. Distribution of all murres during June and July, based on the OCSEAP data base. Data are summarized into 30-minute blocks for display and analysis. Colonies are displayed as filled circles; the size of the circle is proportional to the size of the colonies. Colony data are from Sowls et al. (1978), supplemented by more recent counts where available.

4.2.3.2 Auklets and Murrelets

Smaller alcids in Prince William Sound and the western Gulf of Alaska include Marbled, Kittlitz's, and Ancient Murrelets, and Cassin's, Crested, and Parakeet Auklets. Of these, Marbled Murrelets suffered the greatest mortality in the spill. Although only 2.2 percent of all oiled birds collected on the beach were Marbled Murrelets, this species accounted for 11.6 percent of all oiled birds collected in Prince William Sound. Marbled Murrelets have the center of their nesting population from about Prince William Sound to Kodiak Island. Precise population estimates are unavailable, but the species probably numbers in the tens to hundreds of thousands. The species is present in neritic waters of Prince William Sound and the western Gulf of Alaska all year, with the broadest distribution in summer months. Most sightings at sea have been small groups in bays and other coastal sites. Kittlitz's Murrelets are probably endemic to Alaska and Siberian waters where they, like the Marbled Murrelet, are noncolonial and nest at inland sites. The population is not known, but tens of thousands may be found in Prince William Sound in summer (Sowls et al., 1978). Ancient Murrelets have a nesting population estimated at 400,000 and are most abundant from Kodiak Island to the Shumagins (Sowls et al., 1978). Gould et al. (1982) recorded the most sightings from March through August, with small flock size of up to 35 birds. OCSEAP/USFWS survey data show that concentrations at sea occur in the summer in coastal waters of southeastern Kenai Peninsula, over the shelf east of Kodiak, and in the vicinity of the Semidi Islands.

Cassin's Auklets have an estimated nesting population in Alaska of around 600,000 birds, with the greatest numbers found in the western Gulf of Alaska. OCSEAP/USFWS survey data show that concentrations have been recorded over the shelf southeast of Prince William Sound and south of Kodiak Island. Crested Auklets are boreal in distribution with large colonies in the Bering Sea, the Aleutians, and the Alaska Peninsula as far east as the Shumagins. The Alaska population is estimated to exceed 1 million birds, but probably only a few thousand are found in the western Gulf of Alaska in the summer (Sowls et al., 1978). Waters near Kodiak Island are an important wintering area for Crested Auklets. Parakeet

Auklets have the eastern extent of their distribution in Prince William Sound. While less colonial than most other auklets, they nest at 90 known sites in Alaska, about two-thirds of which are in the western Gulf of Alaska. The Alaska population is estimated at 800,000 birds (Sowls et al., 1978). Colonies in the Gulf of Alaska exist on the Semidis (58,000 birds) and on Afognak Island, the Barren Islands, and the Kenai Peninsula.

In April and May, OCSEAP/USFWS survey data show that murrelets and auklets at sea are widespread at low to moderate densities in Prince William Sound and in shelf waters off the Kenai Peninsula, Kodiak Island, and the Alaska Peninsula. Small alcids are generally undercounted at sea due to their size, cryptic coloration, and evasive behavior.

4.2.3.3 Puffins

Both Horned and Tufted Puffins have breeding colonies in Prince William Sound and the Gulf of Alaska. The Alaska population of Horned Puffins is estimated to be 1.5 million by Sowls et al. (1978), who also estimate the population of Tufted Puffins to be approximately 4 million. Puffins have major breeding colonies in the Chiswell Islands, the Barren Islands, off Kodiak Island, and in the Semidi Islands. The puffins share many characteristics of other alcids, including diving and flocking behavior, that would make them particularly vulnerable to oiling. Possibly because of the timing of their return to breeding stations in 1989, however, they apparently escaped major mortality in this incident.

4.2.3.4 Sea Ducks, Cormorants, Loons, and Grebes

A number of seabird and waterfowl species that have a distinctly neritic distribution are found predominantly in protected waters of bays and inlets. These species include a variety of sea ducks, including Oldsquaw, Bufflehead, and Harlequin Ducks, scoters, eiders, loons, grebes, mergansers, and cormorants. These birds also share a vulnerability to oil spills because of their diving habits and the time they spend on the surface in large flocks. Although only 11.5 percent of all oiled birds collected on the beach were of these species, ducks, cormorants, loons, and grebes accounted for 61.4 percent of all oiled birds collected in Prince William Sound. White-winged Scoters have the center of their breeding range inland in Alaska. They apparently are present year round. Gould et al. (1982) found them to outnumber all other waterfowl. OCSEAP/USFWS survey data show that they are common in Cook Inlet and around Kodiak Island and the Alaska Peninsula. Surf Scoters have been found in low numbers from Unimak Pass eastward, where they favor shallow waters and protected bays (Gould et al., 1982). Pelagic Cormorants have the center of their breeding range in Alaska, where they have a population of about 90,000 (Sowls et al., 1978). They occupy neritic waters year round. Double-crested Cormorants in Alaska number fewer than 10,000; about 8,200 are found on colonies in the western Gulf of Alaska (Sowls et al., 1982). Common Loons account for 56 percent of all loons in Gulf of Alaska waters and can be found in low numbers in shallow waters from summer through winter (Gould et al., 1982). Pacific Loons account for about 39 percent of sightings in coastal waters of the Gulf of Alaska (Gould et al., 1982); Red-throated Loons occur but are rare. Western Grebes also are present but were not recorded by Gould et al. (1982).

4.3 Characteristics of Affected Shoreline

The shoreline of Prince William Sound, Cook Inlet, the Kenai Peninsula, Kodiak Island, and the Alaska Peninsula coast is composed of many types of substrates. These shoreline types have varying characteristics with regard to the processes affecting bird carcass deposition and persistence. Accessibility of the shoreline to personnel involved in bird carcass recovery also varies with shoreline type. Therefore, it was important to obtain data on the composition of the coast on which bird carcasses might be deposited.

4.3.1 Environmental Sensitivity Index (ESI) Data

Coastal environments have been categorized according to the ESI values as an aid to evaluating potential environmental impacts and contingency planning. Indices that rank

shoreline types have evolved over the past 20 years since the basic relationship between shoreline type, oil persistence, and biological sensitivity was first delineated.
ESI incorporates additional sensitive biological resources into earlier indices that reflect persistence of oil in shoreline environments and basic biological considerations (Hayes et al., 1976; Michel et al., 1978; Gundlach et al., 1980). The ESI value increases with increasing environmental sensitivity to oiling, on a scale of 1 to 10. Most U.S. coastlines and many other parts of the world have been ranked according to ESI. ESI data are increasingly available in digital form.

For this study, digital data describing the shoreline types for affected areas of the Alaska coast were obtained from the State of Alaska Department of Natural Resources (ADNR). These data, part of the State/Federal damage assessment data base, were projected to latitude and longitude and converted to DXF format by the ADNR Geographic Information System (GIS) Project for use in this analysis. Separate data bases were provided for the Prince William Sound region, the Kenai Peninsula/Cook Inlet region, and the Kodiak/Alaska Peninsula region. Scoring of shoreline types varied slightly among these data bases (e.g., exposed tidal flats were ESI-5 in Kenai/Cook Inlet, but ESI-7 in Prince William Sound). These discrepancies appear to result from varying permeability and oil persistence characteristics of these shoreline types in the various regions. They were eliminated in creating the combined data base. Data were binned into 235 coastal 15-minute latitude/longitude blocks. Blocks were combined into sectors for some purposes, and where blocks included data on more than one sector, subblocks were constructed. Both block and sector data are used as model input.

4.3.1.1 ESI Classification

Shoreline classifications as described in the ESI documentation for the three regions (RPI, 1985; Hayes and Ruby, 1979; RPI, 1983) include the following:

(1) Exposed rocky shores.

(2) Exposed wave-cut platforms.

(3) Fine- and medium-grained sand beaches.

(4) Coarse-grained sand beaches.

(5) Mixed-sand and gravel beaches.

(6) Gravel beaches.

(7) Exposed tidal flats.

(8) Sheltered rocky shores.

(9) Sheltered tidal flats.

(10) Marshes.

(99) Unclassified.

Exposed rocky shores are common along open coastal areas of the Gulf of Alaska and Prince William Sound. They are composed of steeply dipping to vertical bedrock and are subjected to moderate to high wave action. Some cliffs are seabird nesting sites.

Exposed wave-cut platforms are also very common in the area. They consist of wave-cut or low-lying bedrock terraces and are often very wide (up to several kilometers in parts of Cook Inlet). The surface is irregular, often with a narrow boulder or gravel beach at the high-tide swash zone. These shores are subjected to considerable wave energy.

Fine- and medium-grained sand beaches, which are usually wide and flat, are relatively uncommon in this area. Coarse-grained sand beaches, which usually have a moderate slope, are also relatively uncommon in the area.

Mixed-sand and gravel beaches are very common in the Gulf of Alaska and Prince William Sound. They occur as pocket beaches along rocky shores, as perched beaches on rocky platforms, and as extensive beaches in front of till cliffs. Rates of oil burial may be quite high.

Gravel beaches, which are also common in the area, consist of gravel of varying sizes and may also include shell fragments and woody debris. Oil penetration may be quite deep.

Exposed tidal flats, which are scored variably in the different regions, vary in productivity and oil persistence.

Sheltered rocky shores are relatively common in the affected area. This shoreline type includes rock walls, ledges, boulders, and wide rock platforms in fjords and inlets. Because of decreased wave energy in sheltered areas, oil may persist for a long time.

Sheltered tidal flats share many characteristics of exposed tidal flats, but they are subject to longer oil persistence. Marshes are variably common in the affected areas of Prince William Sound and the Gulf of Alaska. They are extremely sensitive to oil and to intrusion by humans.

Unclassified areas in these data bases are generally small offshore islands. These are especially numerous in the Kodiak/Alaska Peninsula Region.

4.3.1.2 Segmentation of Shoreline Type Data

For purposes of portions of the model analysis, the 15-minute blocks were combined into sectors. These sectors include the affected areas of Prince William Sound, the Kenai Peninsula, Cook Inlet, the Barren Islands, Katmai National Park, Becharof National Wildlife Reserve, Aniakchak National Monument, Kodiak Island, and the Alaska Peninsula and nearby offshore islands, including the Semidi Islands (see figure 4-6). The incidence of shoreline types by sector is summarized in table 4-1 and illustrated in figure 4-7. Detailed information by 15-minute block is included in the tables of appendix B.

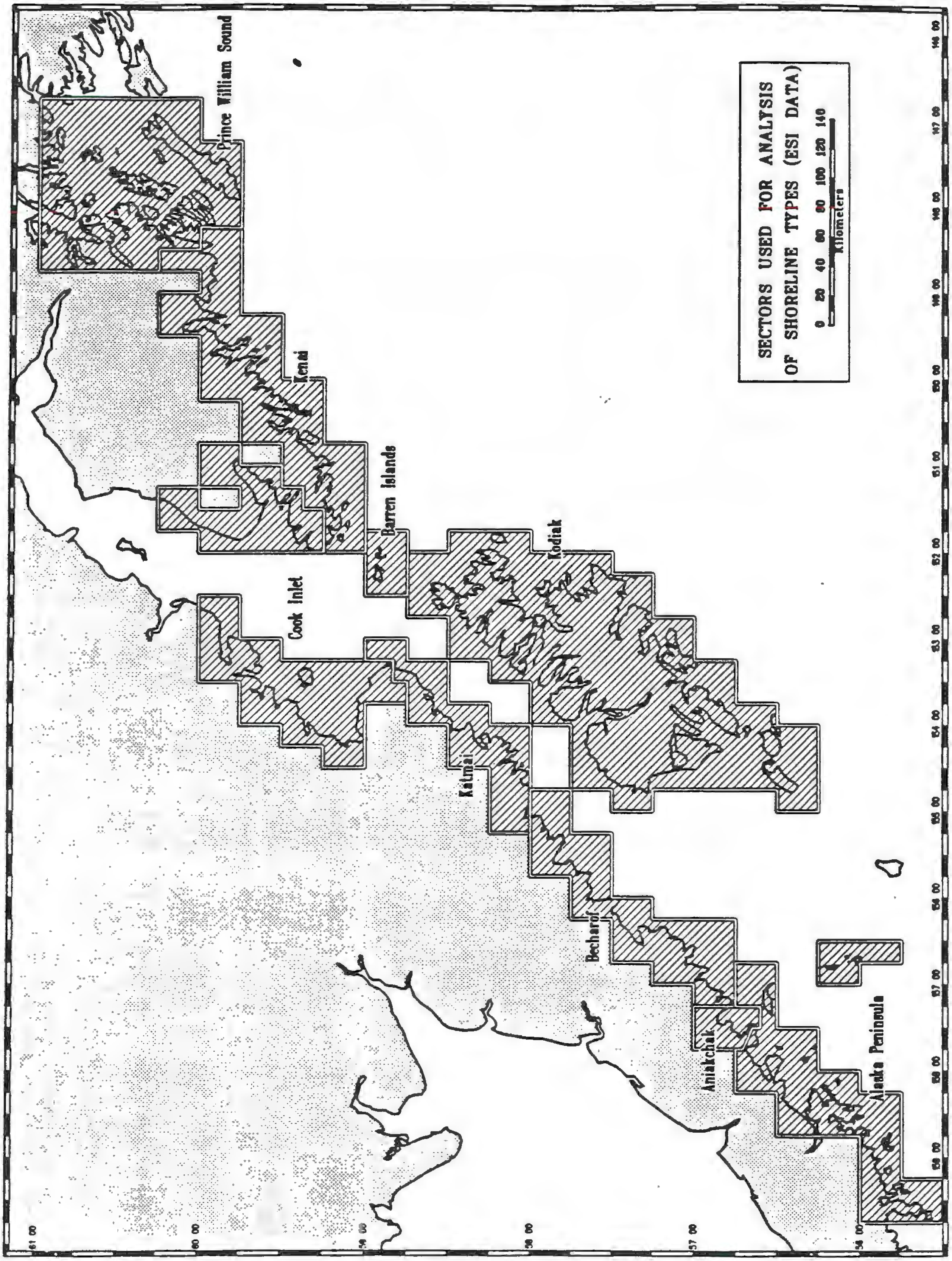


FIGURE 4-6. Location of sectors used for segmentation of shoreline-type data.

TABLE 4-1. Summary of linear coastal distances by sector, from Environmental Sensitivity Index Classification, in kilometers of shoreline (proportions in parentheses). Because of rounding, proportions may not add up to 1.

Sector	Fine/ Med. Sand Beach	Crs. Sand Beach	Mixed Sand/ Grav. Beach	Grav. Beach	Exp. Rocky Shore	Exp. WvCut Platf.	Shelt. Rocky Shore	Exp. Tidal Flat	Shelt. Tidal Flat	Marsh	Ice	Un-clas-sified	TOTAL
PWS	26.45	5.54	932.85	619.60	409.30	276.50	1076.3	2.64	123.00	84.46	22.27	89.38	3668.36
	(0.01)	(0.00)	(0.25)	(0.17)	(0.11)	(0.08)	(0.29)	(0.00)	(0.03)	(0.02)	(0.01)	(0.02)	
KENAI	0.00	9.61	288.7	46.38	675.64	63.59	560.4	37.21	30.01	39.1	6.68	234.4	1991.76
	(0.00	(0.00)	(0.14)	(0.02)	(0.34)	(0.03)	(0.28)	(0.02)	(0.02)	(0.02)	(0.00)	(0.12)	
COOK INLET	24.18	17.55	430.5	35.53	44.2	285.6	288.7	188.9	130.9	206.0	0.00	75.21	1727.44
	(0.01)	(0.01)	(0.25)	(0.02)	(0.03)	(0.17)	(0.17)	(0.11)	(0.08)	(0.12)	(0.00)	(0.04)	
BARREN ISLANDS	0.00	0.00	19.52	2.06	64.38	7.87	0.89	0.00	0.00	0.00	0.00	14.23	108.96
	(0.00)	(0.00)	(0.18)	(0.02)	(0.59)	(0.07)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.13)	
KATMAI	0.00	17.48	237.7	7.04	67.24	102.4	99.1	72.72	109.1	33.35	0.00	37.99	784.24
	(0.00)	(0.02)	(0.30)	(0.01)	(0.09)	(0.13)	(0.13)	(0.09)	(0.14)	(0.04)	(0.00)	(0.05)	
KODIAK	5.51	2.93	1298.4	593.6	388.5	777.6	1115.2	65.81	207.3	52.29	0.00	526.34	5033.7
	(0.00)	(0.00)	(0.26)	(0.12)	(0.08)	(0.15)	(0.22)	(0.01)	(0.04)	(0.01)	(0.00)	(0.10)	
BECHAROF	22.18	21.79	183.6	67.82	82.99	252.1	23.39	55.96	75.85	31.85	0.00	109.7	927.22
	(0.02)	(0.02)	(0.20)	(0.07)	(0.09)	(0.27)	(0.03)	(0.06)	(0.08)	(0.03)	(0.00)	(0.12)	
ANIAKCHAK	6.48	7.87	20.50	15.03	0.14	39.63	3.07	32.27	0.28	7.20	0.00	14.88	147.33
	(0.04)	(0.05)	(0.14)	(0.10)	(0.00)	(0.27)	(0.02)	(0.22)	(0.00)	(0.05)	(0.00)	(0.10)	
ALASKA PEN.	17.18	49.94	203.5	153.7	230.3	212.5	147.2	325.1	22.78	70.61	0.00	183.9	1616.67
	(0.01)	(0.03)	(0.13)	(0.10)	(0.14)	(0.13)	(0.09)	(0.20)	(0.01)	(0.04)	(0.00)	(0.11)	

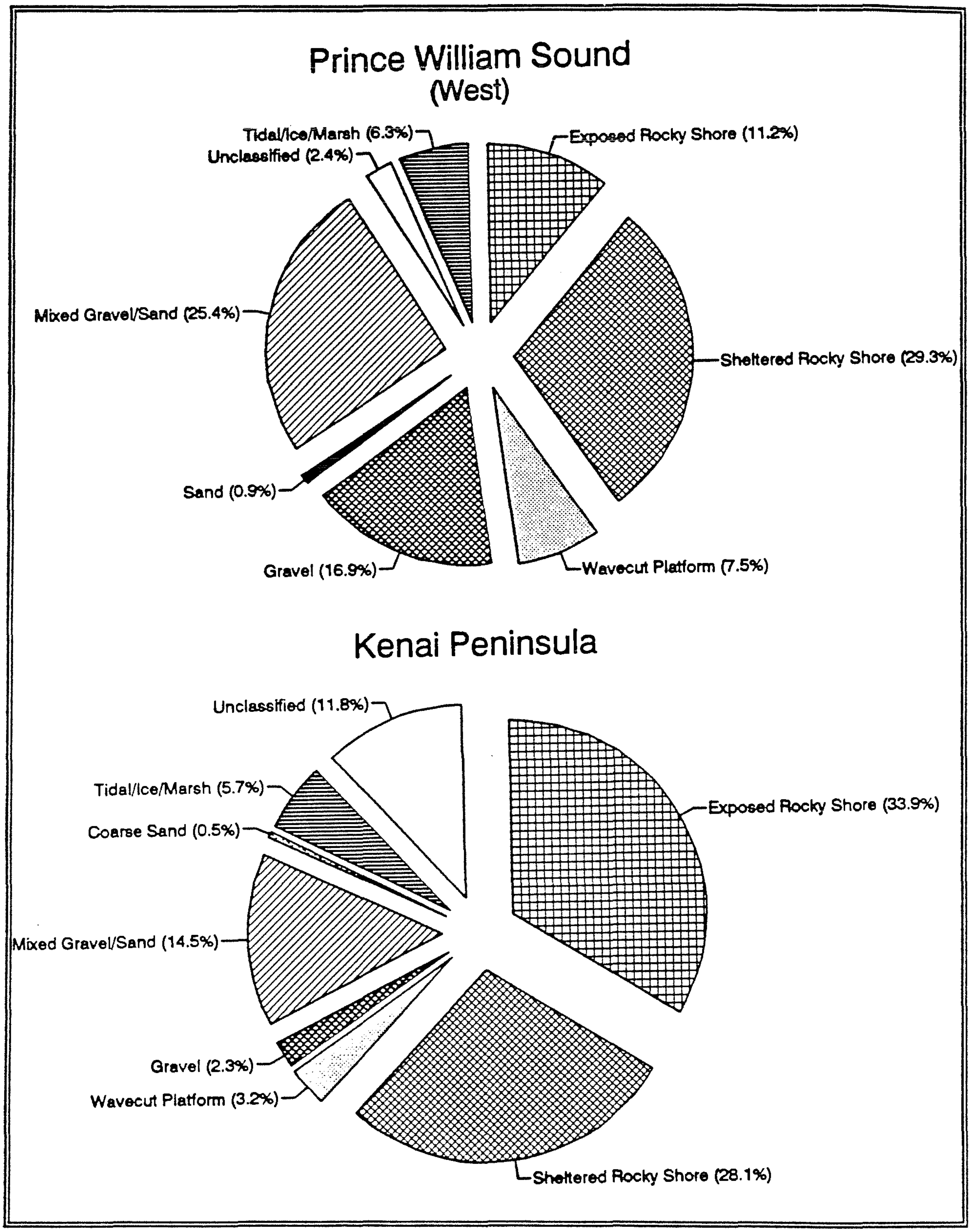


FIGURE 4-7. Relative proportions of shoreline types in individual sections (derived from ESI data).

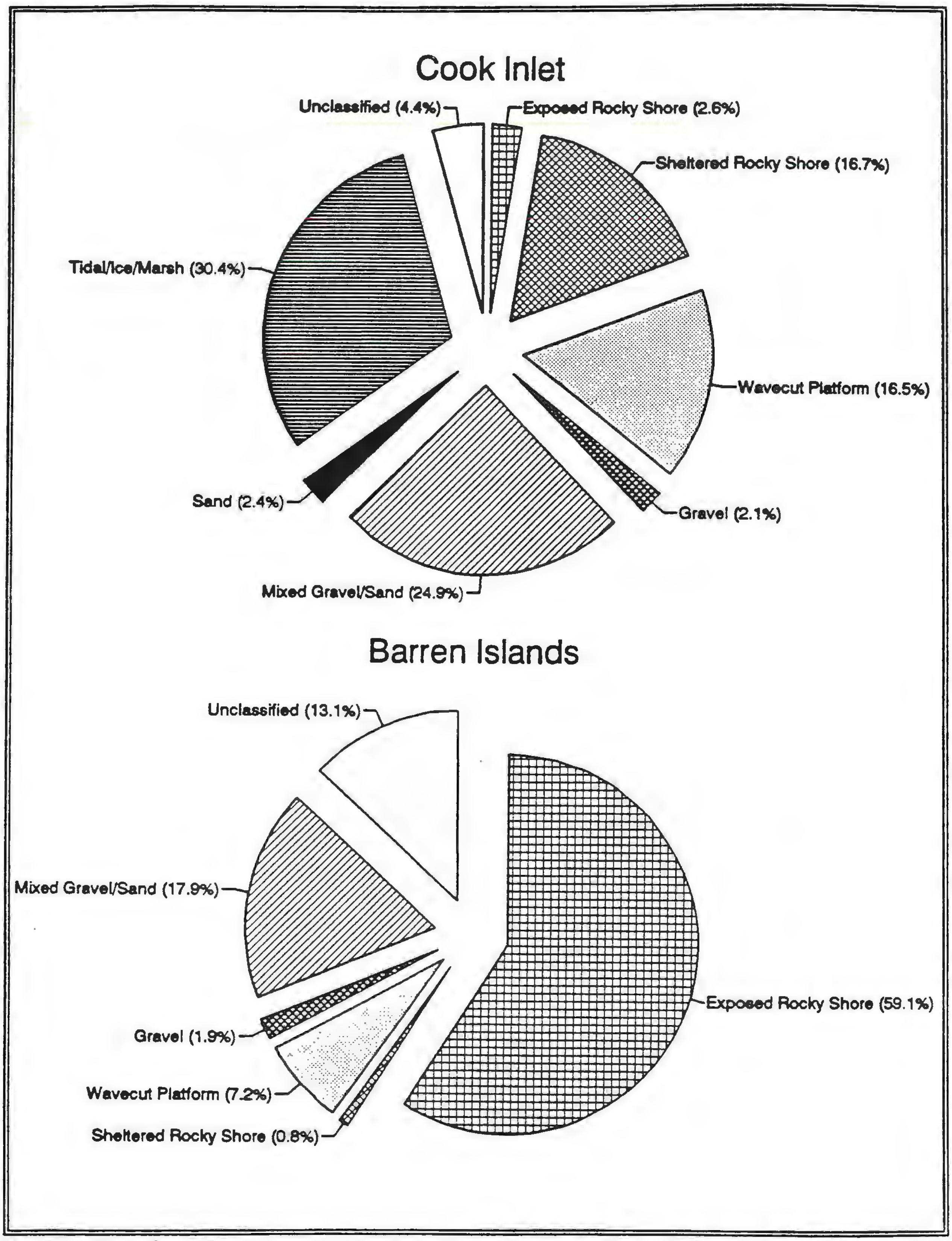
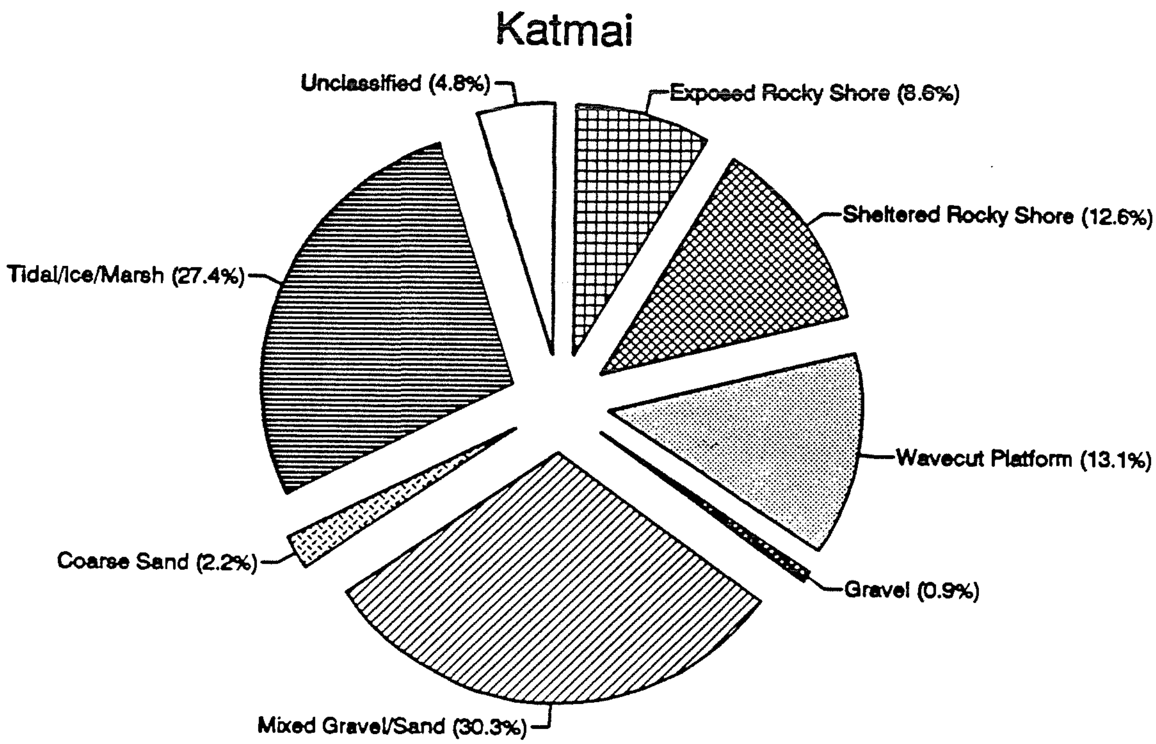


FIGURE 4-7. (Cont'd.)



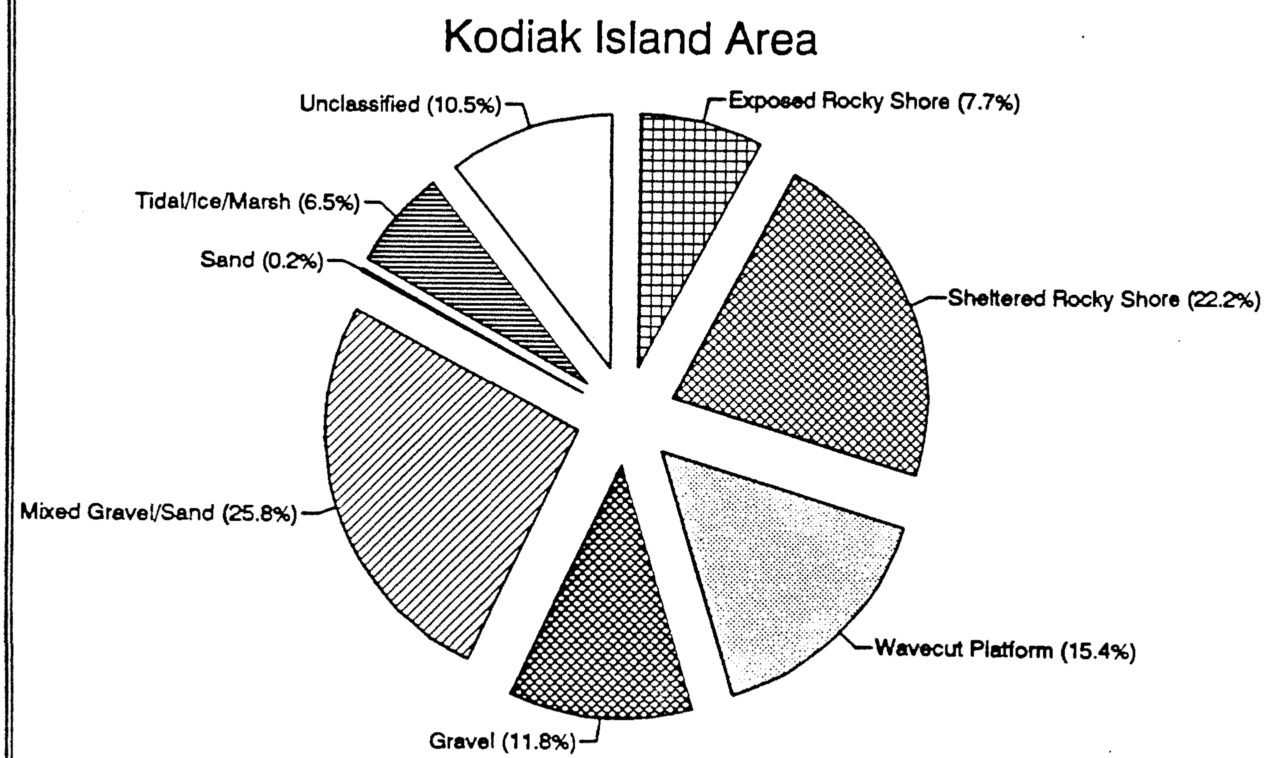


FIGURE 4-7. (Cont'd.)

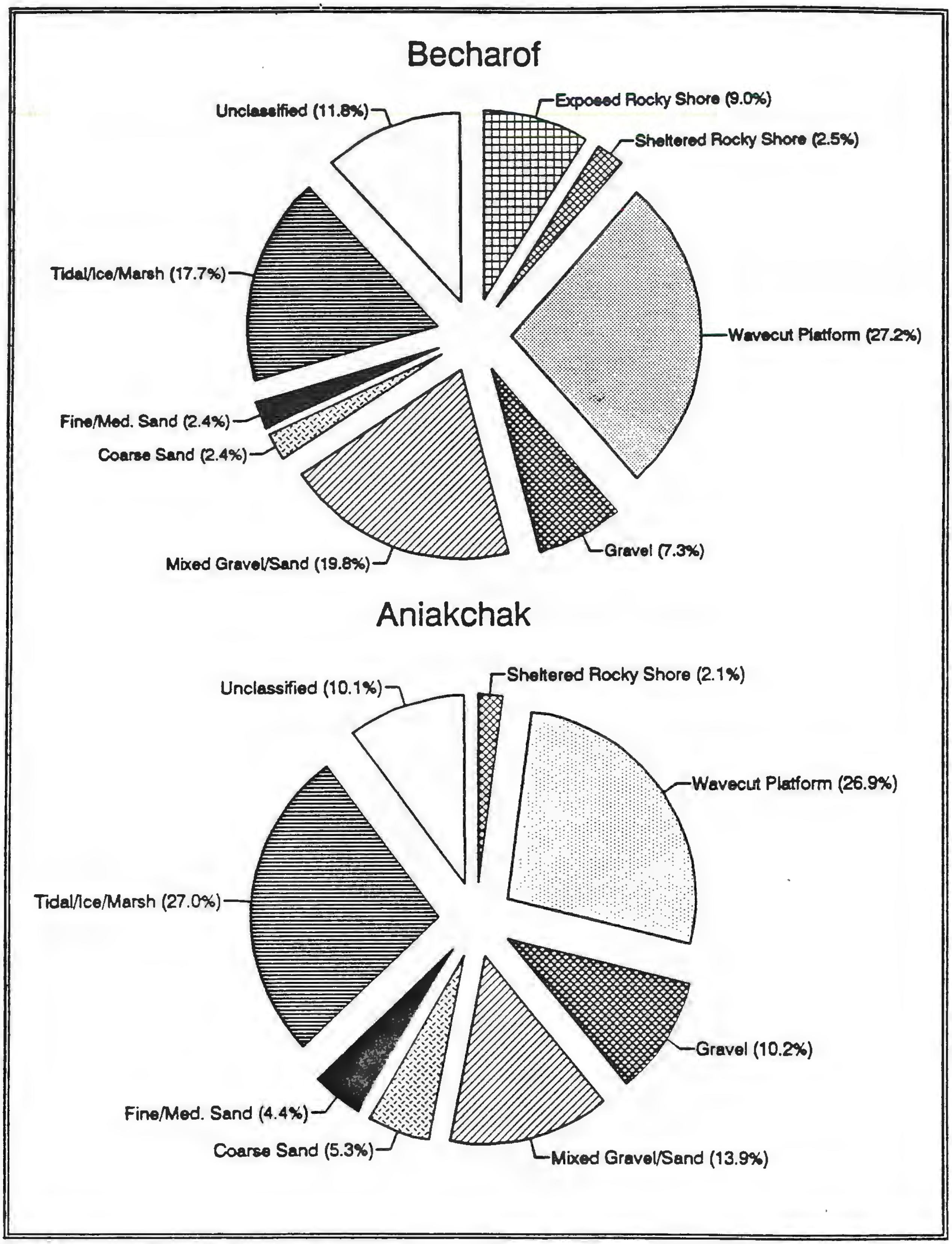


FIGURE 4-7. (Cont'd.)

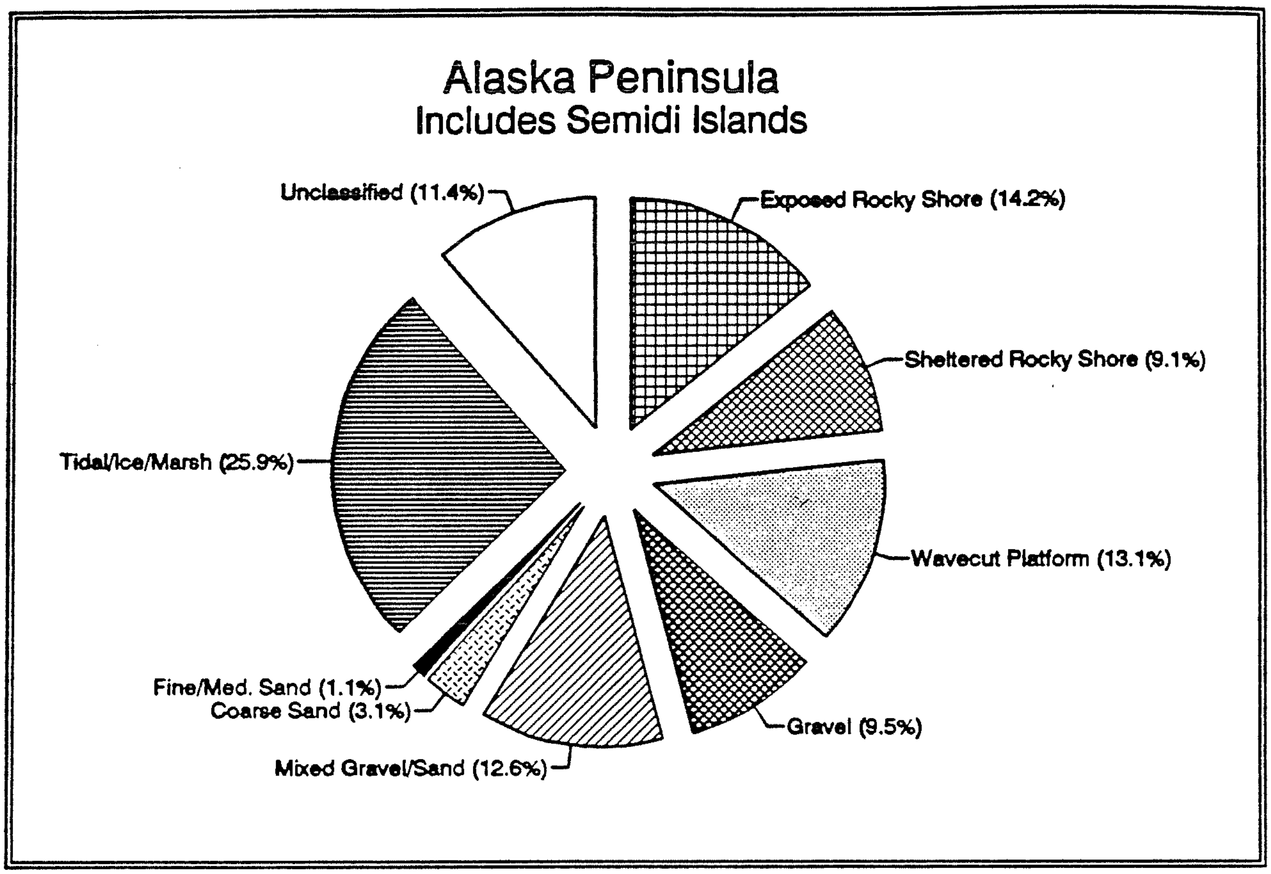


FIGURE 4-7. (Cont'd.)

4.3.2 Use and Limitations of ESI Shoreline Type Data

Shoreline type data were used to provide an indication of probable carcass deposition and persistence patterns and of accessibility to bird recovery crews. Based on definitions of ESI shoreline types and a personal communication with Jeff Dahlin (RPI), shoreline types were rated for deposition potential, burial potential, scavenging potential, and accessibility (see table 4-2). Generally, vertical rock (exposed or sheltered) and ice were assumed to deflect carcasses so that deposition was not possible. Sheltered tidal flat and marsh were considered essentially unsearchable because of sensitivity to intrusion or safety concerns. Wave-cut platforms and gravel beaches presented rating problems because each type encompasses both accessible and inaccessible portions. Small gravel is accessible and some wave-cut platform areas are accessible. However, gravel beaches also include large cobble, a substrate that makes traversing very difficult and slow. Wave-cut platform may be quite bouldery and very wide, rendering effective search nearly impossible. Additionally, boat access in many areas is not possible.

TABLE 4-2. Susceptibility to carcass deposition, burial of carcasses, scavenging of carcasses, and carcass recovery by shoreline type.

	DEPOSITION	BURIAL	SCAVENGING	RECOVERY
Exposed Rocky Shores	No	No	No	No
Exposed Wave-Cut Platforms	Yes	No	Yes	Some
Fine- and Medium-Grained Sand Beaches	Yes	Yes	Yes	Yes
Coarse-Grained Sand Beaches	Yes	Yes	Yes	Yes
Mixed-Sand and Gravel Beaches	Yes	-?-	Yes	Yes
Gravel Beaches	Yes	-?-	Yes	Some
Exposed Tidal Flats	Yes	-?-	Yes	Yes
Sheltered Rocky Shores	No	No	No	No
Sheltered Tidal Flats	Yes	-?-	Yes	No
Marshes	Yes	No	Yes	No
Unclassified	-?-	-?-	-?-	-?-

5.0 SOURCES OF CARCASS UNDERCOUNTS

5.1 At-Sea Loss Rates for Seabird Carcasses

5.1.1 Background and Study Design

A question central to the estimation of the total number of seabirds that die as a result of the *Exxon Valdez* or other oil spills is the probability of a carcass floating long enough to make landfall or, on the other hand, being lost at sea. Few data addressing this question have been available in the past, making it difficult to assess the true effect of oil spills or natural mortality on seabird populations. Carcass recovery rates varying from 10 percent to 100 percent have been found in experiments using gull carcasses where trajectories seemed to be directed toward shore and where potential beaching areas were searched (Hope-Jones et al., 1970; Bibby, 1981). Anecdotal accounts and our own experience indicate that, under some conditions, carcasses may float for well over a month. In other words, the carcasses that wash ashore following an oil spill or a natural death represent a fraction of the original mortality, but the size of that fraction is not known. The purpose of this portion of the study was to determine as accurately as possible the rate at which at-sea loss occurs and some of the factors that may influence that rate.

Our basic technique was to attach small floating radio transmitters to carcasses and to track the carcasses from an aircraft or boat until they either beached or sank. Freshly killed birds were necessary for these experiments so that the carcasses' age and history were known: carcasses recovered on beaches either during or following the spill would inevitably be of unknown age and condition, invalidating any results that could be obtained from the study. Also, our prior experience indicated that carcasses that had been frozen and thawed floated lower in the water and were likely to sink more rapidly than fresh carcasses. In addition to freely drifting carcasses, we also tracked radio-tagged drift buoys (referred to as "dummies"), which were weighted to drift like bird carcasses. The dummies served as controls on the radio-tagged carcasses because dummies could be lost only due to transmitter failure or drifting beyond range of the tracking aircraft and not due to sinking or scavenging. The difference in the loss rates of dummies and carcasses is a measure of carcass loss due to natural processes rather than factors associated with our methodology.

5.1.2 Methods and Level of Effort

5.1.2.1 Collection and Treatment of Specimens

Under authorization of scientific collecting permits PRT-749140 (Federal) and 90-82 (State), ECI personnel collected a total of 176 seabirds. An additional 41 specimens were collected under other permits and were supplied to the project for use in sinking and/or scavenging studies. Information on the species, numbers, and location of collection of specimens is summarized in table 5-1. All birds were collected by shotgun near large colonies outside the area affected by the *Exxon Valdez* oil spill. Of the total 217 seabirds collected, 10 were damaged too badly for use in the experiments and were discarded in the field. Disposition of the remaining 207 carcasses is discussed in sections 5.1.2.3 and 5.4.

Collected seabirds were kept on ice or refrigerated for up to 10 days before being radio tagged and set adrift. Specimens were not frozen because of possible effects on buoyancy. Preliminary work off the State of Washington revealed that the float characteristics of carcasses were altered by freezing, possibly due to the matting of feathers or loss of air from air sacs. Carcasses that had been frozen and thawed initially floated lower in the water and, therefore, might be expected to sink at a faster rate. Therefore, we considered it desirable to use carcasses that were relatively fresh at the time of release.

We oiled a portion of each release group with Prudhoe Bay crude oil (discussed in section 5.1.2.3). For the first two releases (AK1 and AK2), we used fresh crude oil. Later observations of these carcasses showed that much of this oil washed off within a few days of drifting. For subsequent releases, we used crude oil that had been treated to simulate the

TABLE 5-1. Summary of information on the collection of seabirds used in sinking and scavenging studies.

SPECIES	NUMBER	COLLECTION LOCATIONS
Crested Auklet	101	Shumagin Islands
Common Murre	95	Middleton Is./Shumagin Is. Group
Thick-billed Murre	1	Shumagin Islands
White-winged Scoter	9	Cape Pierce/Bristol Bay/Togiak
Surf Scoter	1	Cape Pierce/Bristol Bay/Togiak
Harlequin Duck	5	Cape Pierce/Bristol Bay/Togiak
Pelagic Cormorant	3	Cape Pierce/Bristol Bay/Togiak
Double-crested Cormorant	2	Cape Pierce/Bristol Bay/Togiak
Total:	217	

aging of crude oil on open water. The treatment, which was conducted outdoors, involved pouring oil into galvanized tubs that were half filled with water. For work in Prince William Sound, 1 to 3 liters (L) of oil was used in each of six 15-gallon (gal) tubs and weathered for 5 days (release AK3) or 10 days (release AK4). For work in the Gulf of Alaska, approximately 2 L of oil was placed in 60-gal tubs and gently stirred three or four times a day for a period of 1 week or more. Larger containers and stirring were used to accelerate the aging process. This oil was used for releases AK5 through AK8. The remaining oil had the consistency of fuel oil (Bunker C) and, because of its viscosity, adhered readily to the feathers of immersed carcasses. (Samples of this aged oil were taken before its use for oiling carcasses and are available for analysis, as needed.) We used two degrees of oiling for carcasses, varying the amount of oil applied to the plumage. On the basis of appearance, these classes of oiling were described as (1) moderate and (2) heavy. Moderate oiling of Crested Auklets consisted of immersion until 40 to 50 milliliters (mL) of oil coated the plumage, while heavily oiled Crested Auklets were repeatedly immersed until approximately 150 mL of oil adhered to the plumage. For Common Murres, moderate oiling consisted of approximately 150 mL, while heavy oiling consisted of 300 to 400 mL. Heavy oiling for ducks and cormorants consisted of about 400 mL (no ducks or cormorants received moderate oiling).

5.1.2.2 Radio Transmitters and Attachment

For each radio transmitter, a small streamlined shape of polystyrene foam (a "barge") was constructed to provide a platform. Inside each barge, a Telonics 1C radio tag with a mass of about 15 grams (g) was fixed with epoxy resin (Telonics, Inc., Mesa, Arizona). Each transmitter had a unique frequency (between 148 to 150 megahertz (MHz) and pulse rate. The transmitters were custom made for increased signal strength at the sacrifice of battery life (limited to about 3 months). Barges were hemispherical in shape, measuring about 60 millimeter (mm) at the base and about 35 mm in height (figure 5-1). The barge was weighted on the flat side with a 30 g (1 ounce (oz)) lead weight so that it would be self-righting. When afloat, only about 10 mm of the top of the barge and the 370-mm-long, vertically oriented antenna were above the water surface. The shape was designed to reduce drag and ride low in the water to minimize the "sail" effect. Prior testing of carcasses, with and without barges, conducted in Coos Bay, Oregon, revealed that the drift characteristics of the two sets were virtually indistinguishable. A barge containing a radio tag of known frequency and pulse rate was attached to one leg of each carcass with stainless steel wire. To prevent entanglement, the barge was separated from the carcass by an 80 mm length of stiff brass wire with swivels at each end.

Additionally, polystyrene foam "dummies" were constructed with the approximate size and shape of the bird carcasses. The dummies served as controls on the radio-tagged carcasses because dummies could be lost only due to factors such as transmitter failure or drifting beyond the range of the tracking aircraft and not due to sinking or scavenging. Dummies were also made from foam floats, with the radio tag embedded in the upper curved surface by epoxy resin and with a banana-shaped lead weight wired to the flat underside of the float. The dummies were of two sizes and were weighted differently to approximate the

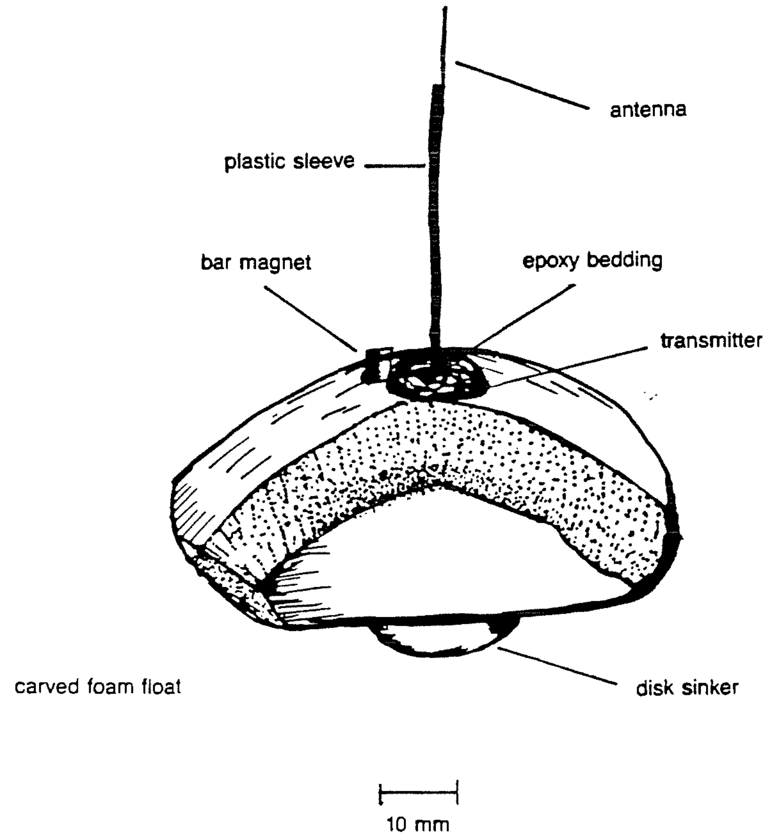


FIGURE 5-1. Barge containing transmitter for radio tracking. Barges were attached to carcasses by a stainless steel tow wire and were designed to ride low in the water to minimize any effect on drift characteristics of carcasses.

size and buoyancy of the carcasses they were designed to simulate. The smaller floats, measuring 125 mm in length with a 115 g (4 oz) lead weight, were used to simulate Crested Auklets. Larger floats measuring 140 mm in length with 115 to 170 g (4 to 6 oz) lead weights were used to simulate Common Murres, ducks, and cormorants (figure 5-2). Initially, dummies drifted along with carcasses in a given release. However, as carcasses began to sink lower in the water, distance between the two groups sometimes increased.

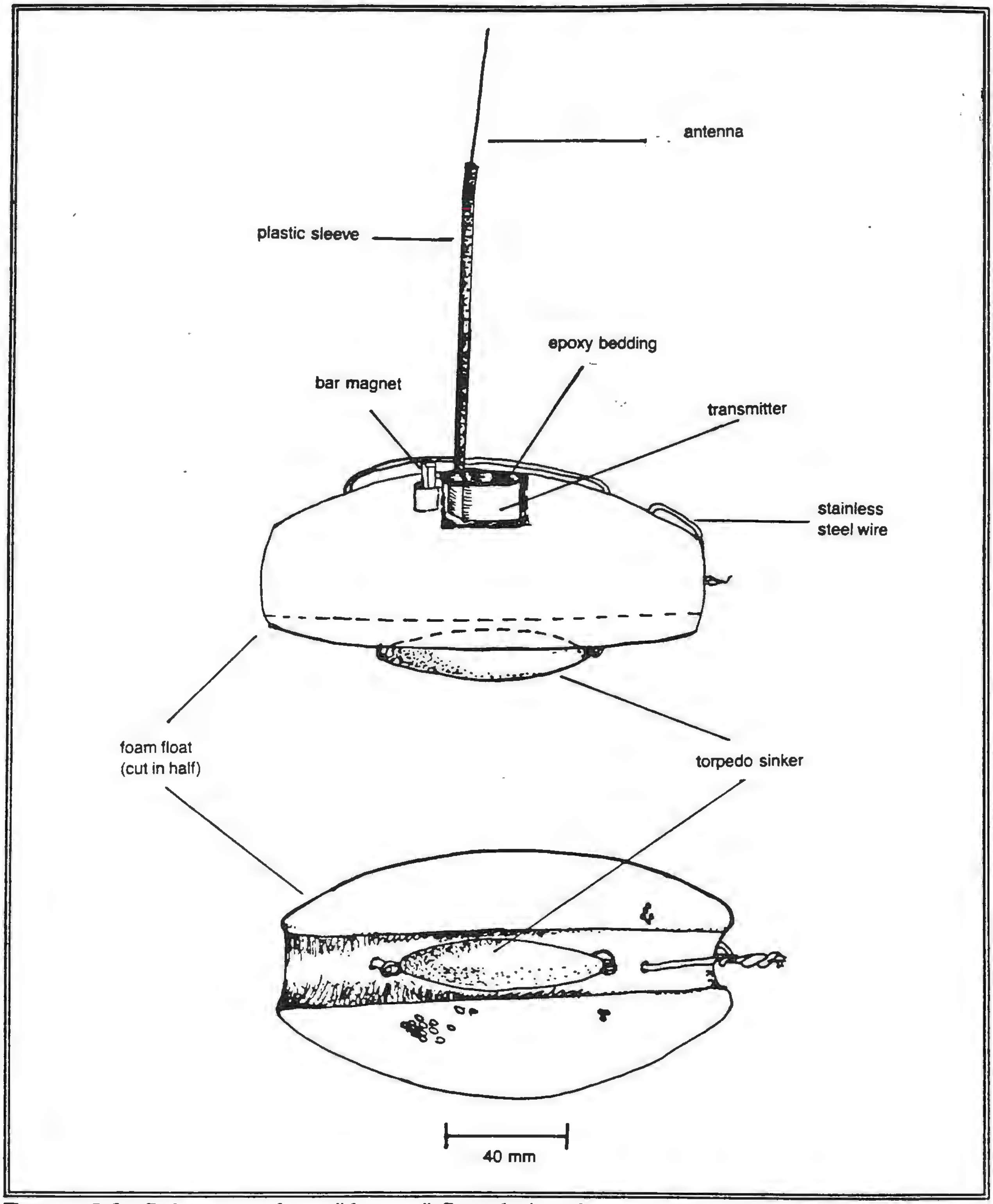


FIGURE 5-2. Polystyrene foam "dummy" float designed to approximate the size and buoyancy of Common Murre, duck, and cormorant carcasses. Smaller floats, weighted differently, were used to simulate Crested Auklet carcasses.

5.1.2.3 Releases

Four releases (AK1 through AK4) were made in Prince William Sound, and four releases (AK5 through AK8) were made in the Gulf of Alaska off Kodiak Island (see figure 5-3). Data on releases are summarized in table 5-2. In each release, carcasses were oiled to varying degrees (unoiled, moderately oiled, or heavily oiled). The numbers of carcasses and degree of oiling are summarized in table 5-3.

Releases of carcasses and dummies in Prince William Sound (AK1 through AK4) were made by a boat team operating out of a base camp on Naked Island. Because our focus was on the loss of carcasses due to sinking or scavenging at sea, release sites were chosen on the basis of the drift conditions at the time of the release to maximize the time that a carcass would drift before beaching. Releases in Prince William Sound were made between 25 May and 17 June 1990. Release AK1 consisted of 20 Crested Auklets and 5 dummies, while release AK2 consisted of 16 Crested Auklets and 4 dummies. In these releases, one-half of the carcasses received moderate oiling, and the other half were unoiled. The third release (AK3) consisted of 20 Common Murre carcasses and 5 dummies. In this release, one-half of the carcasses were unoiled, and the other half were heavily oiled. The last release in Prince William Sound (AK4) consisted of 15 sea ducks, 5 cormorants, and 4 dummies. Eight sea ducks and one cormorant were heavily oiled, and the remainder were unoiled. (In this release, two of the four dummies were weighted to float like the smaller ducks, and two were weighted to float like larger ducks and cormorants). In all, a total of 94 radio tags, placed on 76 carcasses and 18 dummies, were released in Prince William Sound.

Four releases (AK5 through AK8) were made during the Gulf of Alaska phase of the study off the northeast end of Kodiak Island between 18 July and 12 August 1990. Three of the four releases were made from a boat, and, due to heavy seas, the fourth release was made from a helicopter. As in Prince William Sound, release sites were chosen to maximize the time that a carcass would float before beaching. Each of the four Gulf of Alaska releases consisted of 18 Common Murre carcasses, 9 Crested Auklet carcasses, and 9 dummies (6

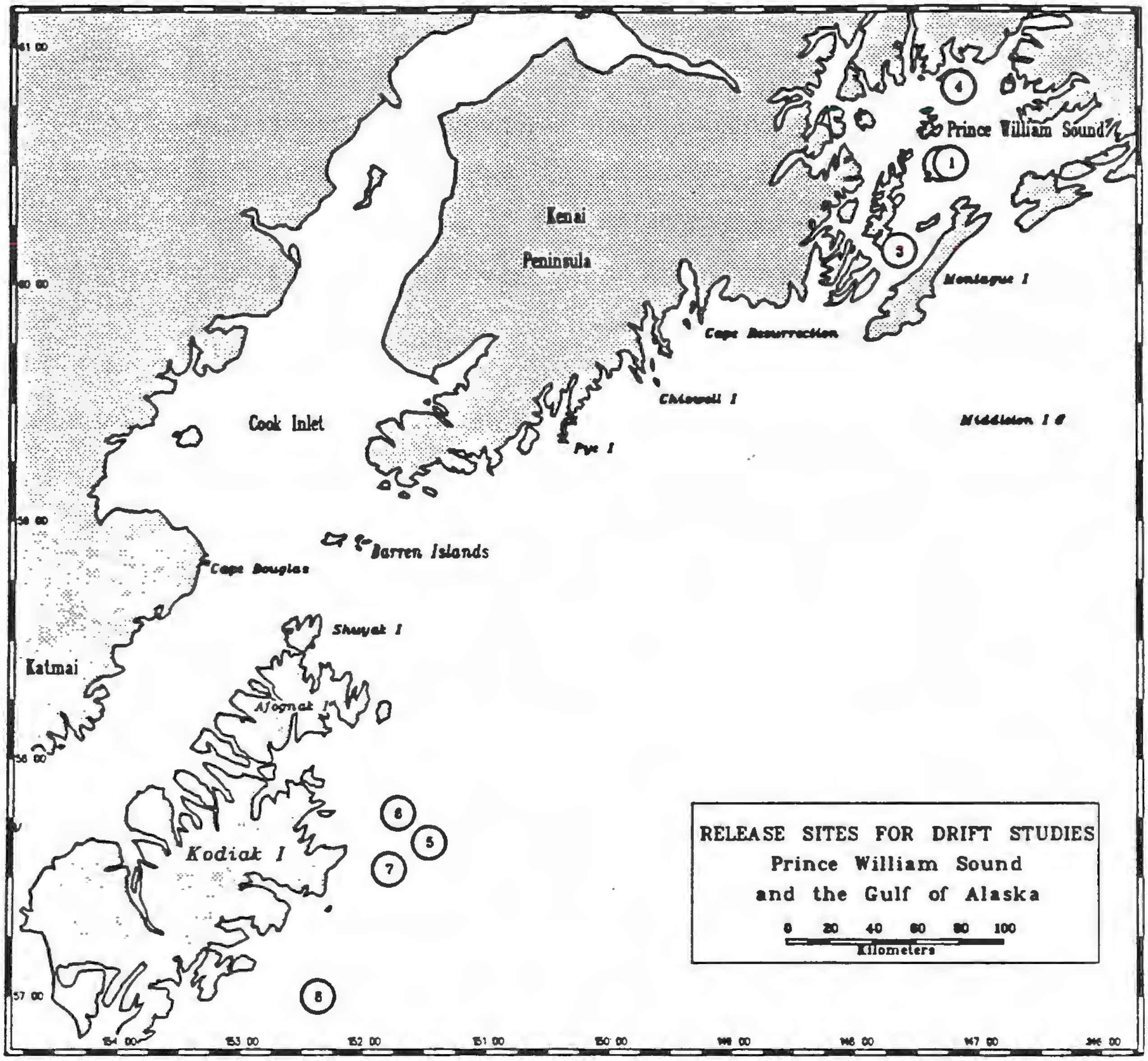


FIGURE 5-3. Release sites for the carcass drift studies in Prince William Sound and near Kodiak Island. Releases 1-4 were made between 25 May and 17 June 1989; Releases 5-8 were made between 18 July and 12 August 1989.

dummies were weighted to float like murres and 3 to float like auklets). Of the Common Murre carcasses in each release, six were unoiled, six were moderately oiled, and six were heavily oiled. Similarly, three of the Crested Auklet carcasses were unoiled, three were

TABLE 5-2. Releases of bird carcasses and dummies for at-sea loss rate studies, spring-summer 1990.

RELEASE NUMBER	DATE	NUMBER OF CARCASSES	BIRD SPECIES	NUMBER OF DUMMIES	LOCATION OF RELEASE
AK1	25 May	20	CRAU	5	60° 30.29' N/ 147° 14.60' W
AK2	28 May	16	CRAU	4	60° 30.04' N/ 147° 19.30' W
AK3	12 June	20	COMU	5	60° 08.30' N/ 147° 39.20' W
AK4	17 June	9	WWSC	4	60° 9.50' N/ 147° 10.50' W
		1	SUSC		
		5	HARL		
		3	PECO		
		2	DCCO		
AK5	18 July	18 9	COMU CRAU	9	57° 39.80' N/ 151° 28.00' W
AK6	24 July	18 9	COMU CRAU	9	57° 46.20' N/ 151° 43.10' W
AK7	6 Aug.	18 9	COMU CRAU	9	57° 32.00' N/ 151° 47.50' W
AK8	12 Aug.	18 9	COMU CRAU	9	57° 00.00' N/ 152° 22.00' W
Totals:		184		54	

CRAU	=	Crested Auklet	HARL	=	Harlequin Duck
COMU	=	Common Murre	PECO	=	Pelagic Cormorant
WWSC	=	White-winged Scoter	DCCO	=	Double-crested Cormorant
SUSC	=	Surf Scoter			

TABLE 5-3. Numbers of carcasses and degree of oiling for releases in Prince William Sound and the Gulf of Alaska.

RELEASE	UNOILED	MODERATE OILING	HEAVY OILING	TOTAL
AK1	10	10		20
AK2	8	8		16
AK3	10		10	20
AK4	11		9	20
AK5	9	9	9	27
AK6	9	9	9	27
AK7	9	9	9	27
AK8	9	9	9	27
Totals:	75	54	55	184

moderately oiled, and three were heavily oiled. A total of 144 radio tags, placed on 108 carcasses and 36 dummies, were released off Kodiak Island.

5.1.2.4 Radio Tracking

Early in the field phase of the project, data were collected on signal strength (amplitude) as the aircraft flew by a floating transmitter at different distances. Initially, the aircraft, an amphibious Grumman Goose, landed on the water in Prince William Sound and transmitters on foam floats were released. The location of each release site was known from Long Range Navigation (LORAN)-C and very low frequency (VLF)-Omega navigation computers aboard the aircraft. Because LORAN-C fixes were found to be unpredictable in Prince William Sound, readings from the VLF-Omega navigation system were used to recalibrates data from the LORAN-C system at 5- to 10-minute intervals. The aircraft, equipped with both high- and low-gain antennas, flew a pattern of parallel track lines at increasing distances from the transmitters to collect data on the relationship of amplitude (signal strength) to distance. The relationship was basically linear, with amplitude declining as the distance increased in a straight line. The results of a regression analysis were used as a basis for constructing tables of distance as a function of amplitude for two aircraft altitudes, 500 and 1,500 ft above sea level (ASL). Close correspondence was found between the actual distances (known from LORAN fixes) and estimates obtained from the regression equation (table 5-4).

TABLE 5-4. Agreement of the estimated distance derived from signal amplitude with the actual distance from calibration trials run in May 1990. The measure of the fit of regression equation to data is expressed as a coefficient of determination (r square; n = number of trials).

ALTITUDE	LOW-GAIN ANTENNAS	HIGH-GAIN ANTENNAS
500 ft ASL	r square = 0.91 n = 42	r square = 0.93 n = 56
1,500 ft ASL	r square = 0.86 n = 56	r square = 0.91 n = 68

To fix the position of a telemetry target, the bearing of the target from the aircraft must be known. From a slow-moving ship or a land station, the antenna array is turned in a direction to obtain maximum signal strength. In an aircraft, this bearing is always assumed to be 90° from the aircraft's heading, which is the point of closest approach of the aircraft to the transmitter (the right-angle distance). At this bearing, the signal amplitude reaches its peak value. In our study, the operator who monitored right- and left-side antenna arrays through a head-set clearly knew which side of the aircraft was receiving signals. (Signal strength from the opposite antenna array was very weak because of shielding caused by the aircraft fuselage). For a given frequency and pulse rate (which identified a transmitter), signal amplitude was monitored continuously and recorded through an analog-to-digital interface board into an onboard computer. Records were made every 10 seconds that included, among other data, the LORAN output, the signal amplitude, and the aircraft position (latitude/longitude) and heading. As a visual check of the increase and decline in amplitude as the aircraft passed near a transmitter, the computer graphed the changing amplitude values. The amplitude of signals from up to five transmitters could be displayed on the computer screen simultaneously. Data on aircraft position and heading were logged to disk at the time of peak signal for later calculation of transmitter position.

This technique was developed to provide a means to conduct an inventory of the status of each transmitter and determine its approximate location. Initially, the general location of each transmitter was determined from the bearing and amplitude. Using an on-screen map of the search area, the likely position could be plotted quickly and, if it was in open water, precision obtained from this method was considered adequate. If the transmitter position appeared to be on or near land, the precise location was determined by boxing in the signal from 500 ft using the low-gain antennas until the aircraft was over the transmitter. In Prince William Sound, the position of most transmitters on any flight was determined by this boxing-in technique. In the Gulf of Alaska, the use of signal amplitude as an indication of distance was employed more often due to the greater search area of open water.

From 25 May 1990 through 31 August 1990, we conducted 40 radio-tracking flights over Prince William Sound and the Gulf of Alaska off Kodiak Island. Twenty tracking flights (approximately 90 hours (h) of flight time) were carried out in Prince William Sound from mid-May to early July. An additional 20 tracking flights (approximately 85 h of flight time) were conducted in the Gulf of Alaska off Kodiak Island. The aerial tracking effort is summarized in table 5-5. Radio-tracking flights were made in a turbine-powered Grumman Goose equipped with two sets of antennas, a low-gain pair effective at short range and a high-gain pair effective at longer ranges. The high-gain antennas were three-element Yagi antennas mounted near the distal end of the aircraft wings with elements vertical to the horizon. The low-gain antennas were omnidirectional antennas 15 centimeters (cm) long, located under each wing near the fuselage. The coaxial leads from the antennas were fed into three Telonics TAC-2-RLB switch boxes in a manner that allowed the operator, through

TABLE 5-5. Summary of aerial tracking effort in Prince William Sound and the Gulf of Alaska.

OPERATION AREA	MONTH	NUMBER OF FLIGHTS	HOURS IN AIR
Prince William Sound	May	4	15
(25 May to 3 July)	June	15	70
	July	1	5
Kodiak/Gulf of Alaska	July	7	20
(11 July to 31 August)	August	13	65
Totals:		40	175

various switch settings, to receive a signal from either the high- or low-gain antennas and from one or both sides of the aircraft. The telemetry-receiving equipment consisted of a Telonics TR-2 receiver with a 2 MHz frequency band width (148 to 150 MHz), a TS-1 scanner/programmer, and a TDP-2 digital data processor. This receiving equipment was modified to feed output data directly to an onboard computer to permit viewing of amplitude curves in real time. Output from the aircraft LORAN-C (periodically adjusted using a VLF-Omega navigation system) was also logged directly into the onboard computer. Two technicians were present on each flight, one to select and monitor signals via the receiver and the other to monitor data entry into the onboard computer.

The high-gain antennas had a useful listening range of about 20 nautical miles (nmi) at 500 ft and 25 nmi at 1,500 ft. The higher altitude (ceiling permitting) was typically used for initial signal acquisition, while the lower altitude was used to determine the location of a carcass or dummy if it was believed to be on or near land. The low-gain antennas had a useful range of about 7 nmi. The location of free-drifting radio-tagged carcasses and dummies was determined either by making runs along a straight-line course (i.e., using the computer to plot the amplitude curve) or by the observer verbally reporting peak amplitude directly from the receiver readout to the computer operator. When runs were made, the amplitude curves of up to five radio tags could be monitored at once. In general, amplitude runs were made using the high-gain antennas, whereas both the high-gain and low-gain antennas were used when the observer was reporting the peak amplitude directly from the receiver output. If the signal from a tag indicated that it might have beached, we flew along the coastline near the signal source at an altitude of 500 ft ASL, with one low-gain antenna pointing over land and the other pointing over the water. As the aircraft passed the signal source, we could easily detect whether the tag was on the land or on the water side of the aircraft. To the maximum extent practical, we attempted to reacquire each transmitter signal on each flight day and record its location. However, the primary purpose in locating radio tags was to determine whether they were still afloat or whether they had beached. The last-recorded location was used principally to define the approximate area in which to begin searching for the tag on the next flight day.

In addition to using aerial tracking, the boat crew based on Naked Island also surveyed parts of Prince William Sound where signals from radio tags had been received. Often, the apparent location of a carcass or dummy on or near a beach was communicated to the boat crew by radio-telephone; then, they verified the location and/or recovered the tag. From the boat, the location of radio tags was determined through triangulation from two or more bearings or by direct visual sighting of a floating or beached carcass or dummy. The receiving equipment used aboard the boat consisted of a Wildlife Materials, Inc., TRX1000S receiver, and a four-element Yagi or a two-element "H" antenna. To locate a carcass or dummy presumed to be on land, the beach area was searched using the same receiving equipment.

5.1.3 Findings

5.1.3.1 Signal Acquisition and Tracking Results

5.1.3.1.1 Prince William Sound

Position fixes were made more than 1,000 times for the 94 radio-tagged carcasses and dummies released in Prince William Sound. Here, the boat team also obtained numerous position fixes, of which some resulted from revisiting waters near release sites in days following a release and some resulted from special searches of beaches or nearshore waters after signals from these areas were acquired by the tracking aircraft. All dummies were tracked until beaching or termination of the Prince William Sound phase of the study. No transmitter failures were encountered, nor did any dummy drift beyond range; although several carcasses and dummies did actually drift out of Prince William Sound, they were still tracked. Our results therefore reflect only the loss of carcasses due to sinking or scavenging at sea, rather than to other factors.

The Prince William Sound phase of the project extended from late May into early July, and, during this time, four releases were made and radio tags tracked on 20 flights. Release AK1 was tracked for the entire period, while later releases were tracked shorter periods of time. Table 5-6 presents the number of tracking days and median persistence times for releases in Prince William Sound. The median persistence time (number of days after release when 50 percent of the total carcasses had been lost at sea) was calculated from a dataset that, for a given day, included only those carcasses that were floating or had beached after the last carcass sinking occurred. Releases AK1 and AK2 remained floating somewhat longer than releases AK3 and AK4, probably due to very calm wind conditions and sea states of Beaufort 0 and 1, which prevailed during this period. Releases AK3 and AK4 were at sea during periods with greater wind and wave action and disappeared more rapidly.

TABLE 5-6. Median persistence time of radio-tagged carcasses (rounded to nearest number of days); includes carcasses that refloated after beachings of fewer than 5 days.

RELEASE NUMBER	DURATION OF TRACKING PERIOD (DAYS)	SAMPLE SIZE	MEDIAN PERSISTENCE TIME (DAYS)
Prince William Sound			
AK1	32	12	20
AK2	38	6	18
AK3	21	3	* 15-18 combined
AK4	16	4	*
Gulf of Alaska			
AK5	20	27	11
AK6	14	27	7
AK7	17	27	9
AK8	19	27	18

(*) For releases AK3 and AK4, median persistence time was not calculated because of the small sample size. Sample size is defined as the number of carcasses that were floating or had sunk as of the day of the last carcass sinking.

For the Prince William Sound data, four classes of fate of carcasses were considered: (1) carcasses that were afloat in open water, (2) carcasses that were beached (verified by inspection or a beach-overflight at 500 ft above ground level (AGL) using low-gain antennas), (3) carcasses that had been removed or scavenged while ashore, and (4) carcasses that had disappeared through sinking or scavenging at sea. The rules used to assign a fate to carcasses between fixes are shown in table 5-7. Data collected from the Prince William Sound releases are shown in figures 5-4 through 5-7. For release AK1, consisting of Crested Auklets, no loss was found in the first 8 days of tracking (figure 5-4b). However, by day 23, we could account for only 70 percent of the carcasses. In other words, 30 percent of the total release had sunk or been scavenged at sea over a 2-week period. (It should be remembered that, for this and the other releases, we accounted for all of the dummies.) Of the remaining

TABLE 5-7. Assignment of the fates of carcasses for figures 5-4 through 5-7. Letters in the body of this fate-transition matrix give the fates of carcasses on day between sampling dates (t and t+n) or after the last sampling date for that carcass (last column). Fates were Floating, Sunk, Ashore, Removed (retrieved or scavenged), and Indeterminate. A and R were combined in figures 5-4 to 5-7.

		FATE ON DAY t+n				FATE UNKNOWN[1]
		F	S	A	R	
Fate on Day t	F	F	I	I	I	I
	S	n/P[2]	S	n/P	n/P	S
	A	I	n/P	A/I[3]	A	A/I
	R	n/P	n/P	n/P	R	R

[1]This column gives the fates when t was the last day on which data were obtained for the given carcass.

[2]n/P = not permitted

[3]Carcasses that had been ashore more than 3 days prior to day t, where classified as Ashore, and Indeterminate otherwise.

70 percent, only one (5%) was floating after day 23, and by day 32, this carcass had beached or moved into the surf zone. Median persistence time for AK1 carcasses was 20 days. The release site for AK1 was east of Smith Island in the center of Prince William Sound. Over the tracking period, most of the carcasses and dummies drifted in a northeasterly direction toward the Valdez Arm (see figure 5-8).

Release AK2 differed from AK1 in that the decline in carcasses afloat began between day 3 and day 6 and all but one had sunk or beached by day 16 (figure 5-5). Twenty-five percent of the total were lost due to sinking or scavenging at sea by day 20. Median persistence time was 18 days. Release AK2, which also consisted of Crested Auklets, was released south of Smith Island near the release site of AK1. Even though only 3 days had

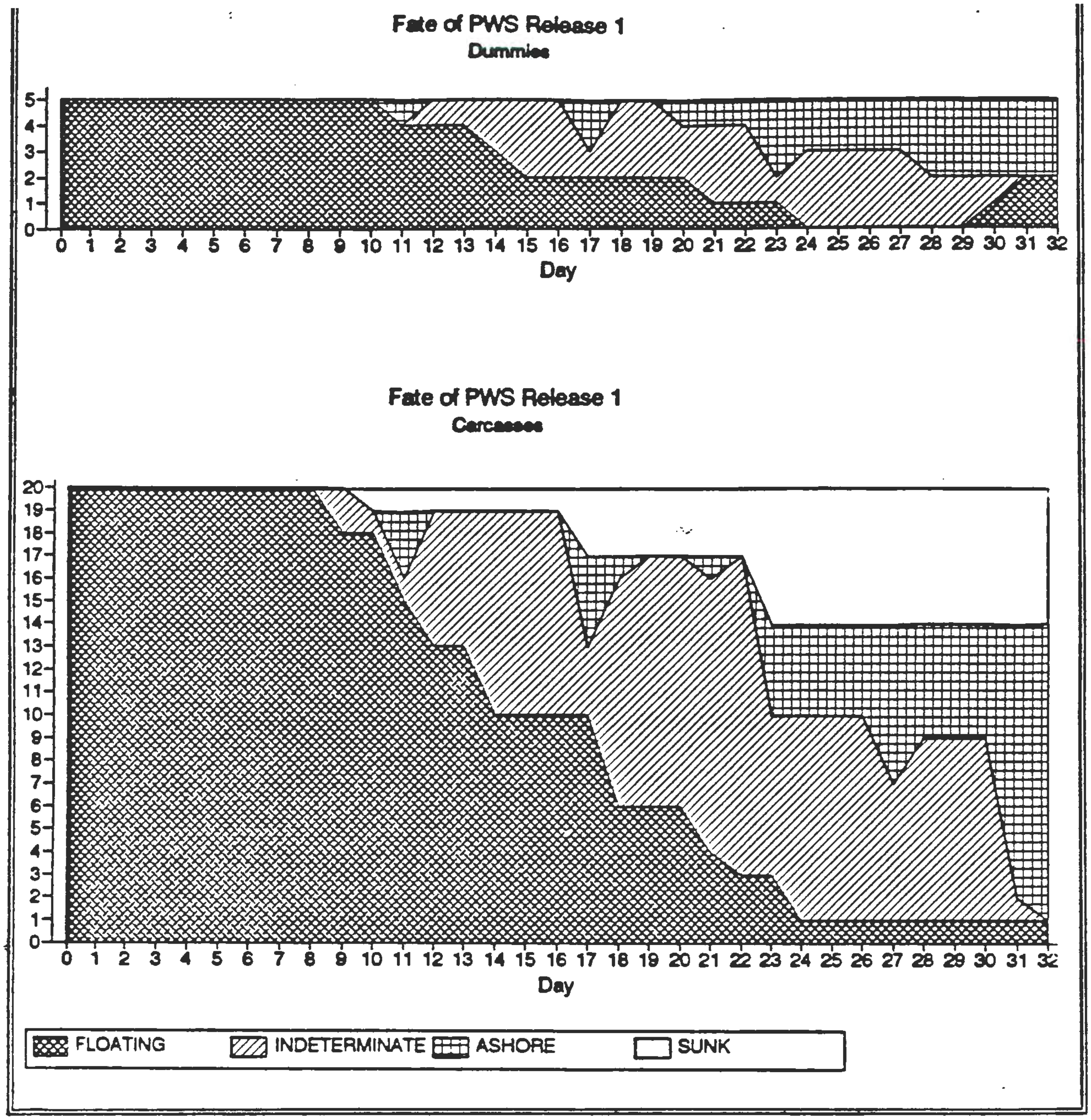


FIGURE 5-4. Fate of dummies and carcasses in Prince William Sound, Release #1. The width of each band indicates the number of carcasses or dummies in each state. The indeterminate state applies to carcasses or dummies between dates on which their status was known to have changed (table 5-7). The tag that was still floating on day 32 had been ashore for several days, and the transmitter was probably no longer attached to the carcass.

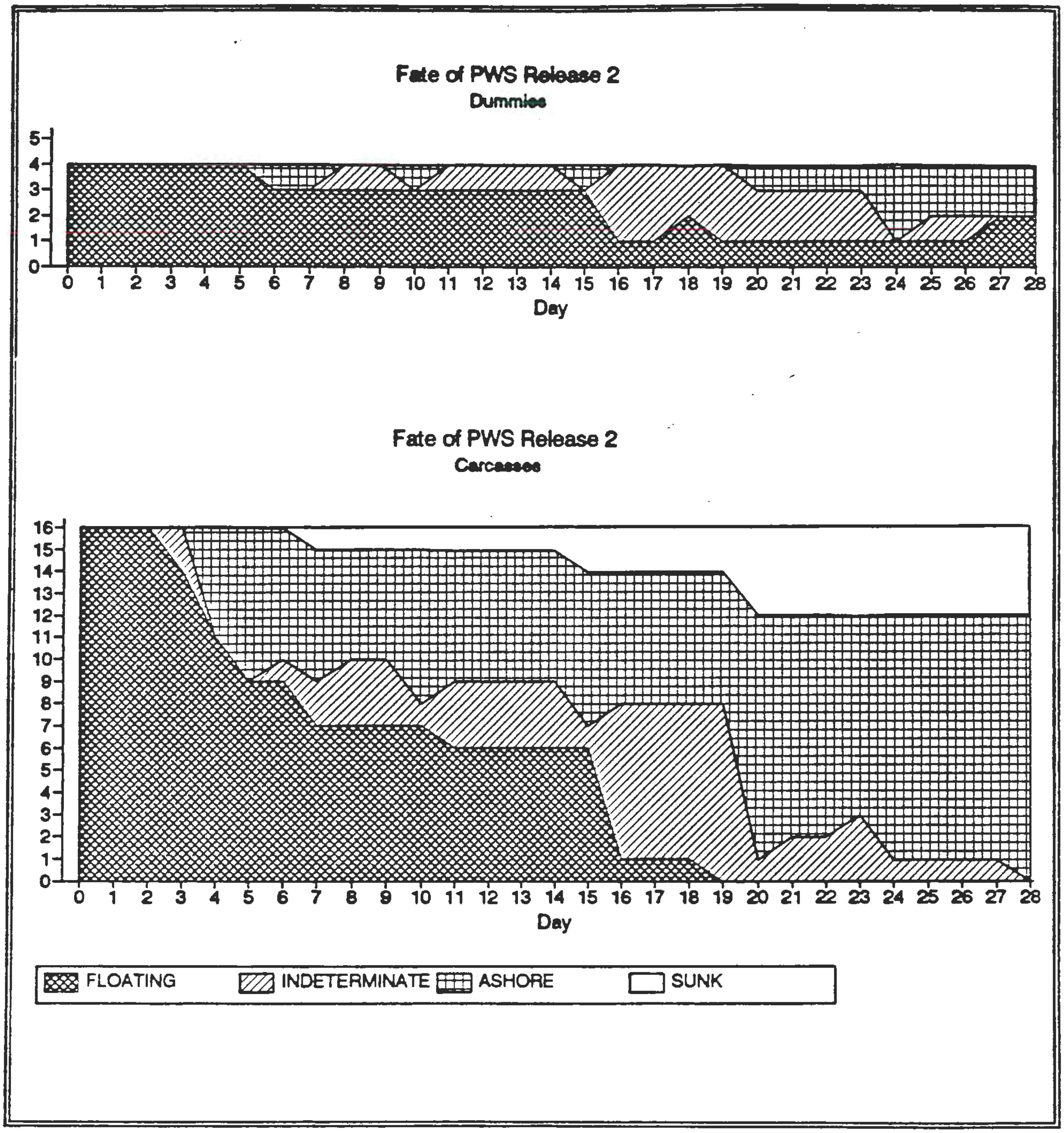


FIGURE 5-5. Fate of dummies and carcasses in Prince William Sound, Release #2. The width of each band indicates the number of carcasses or dummies in each state. The indeterminate state applies to carcasses or dummies between dates on which their status was known to have changed (table 5-7).

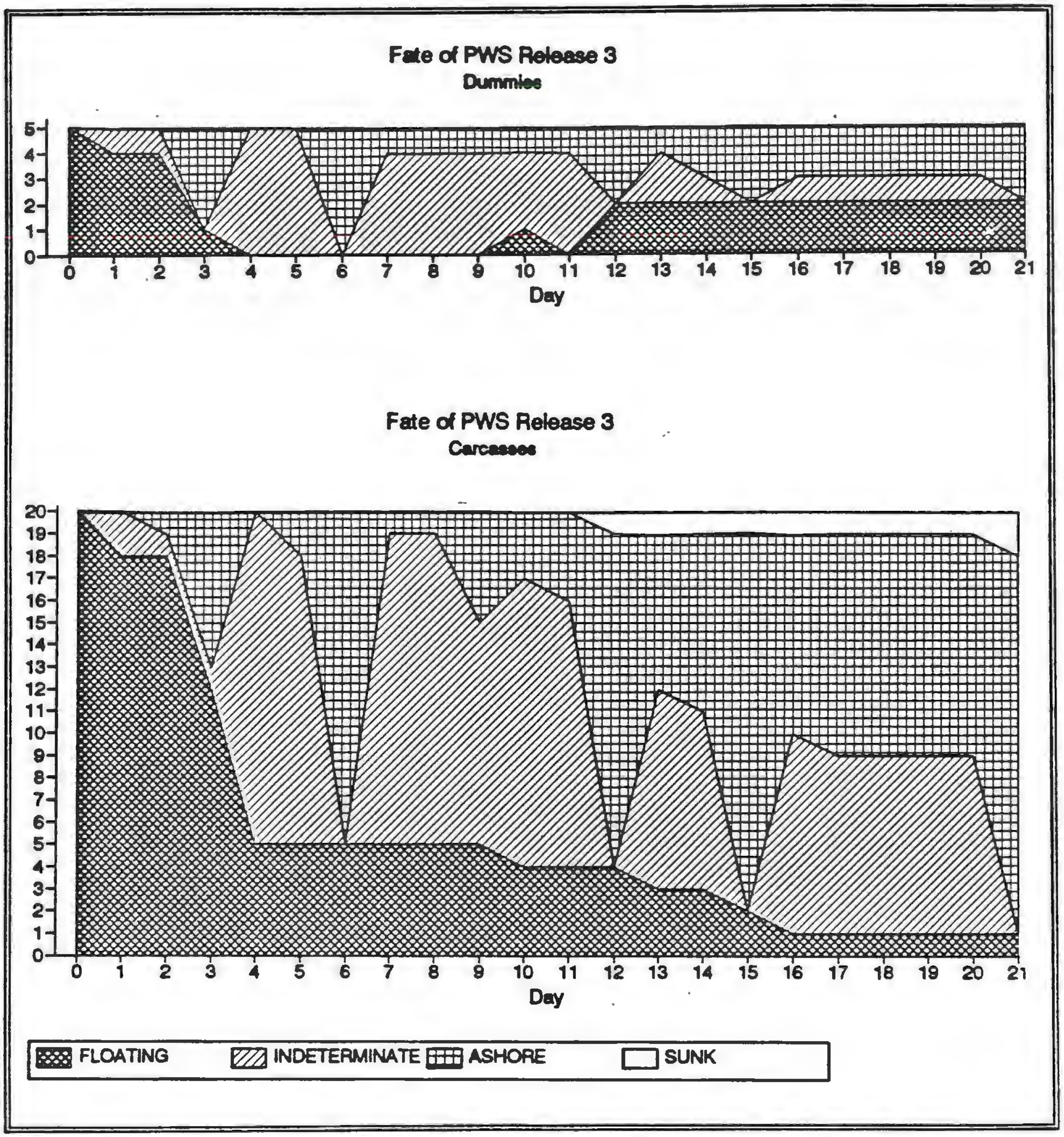


FIGURE 5-6. Fate of dummies and carcasses in Prince William Sound, Release #3. The width of each band indicates the number of carcasses or dummies in each state. The indeterminate state applies to carcasses or dummies between dates on which their status was known to have changed (table 5-7). This release was blown ashore on Green Island following a wind reversal shortly after the tags were set adrift. Reflotation of both dummies and carcasses occurred frequently with this release. The tags floating at the end of this release had been ashore and were probably transmitter barges that were no longer attached to carcasses.

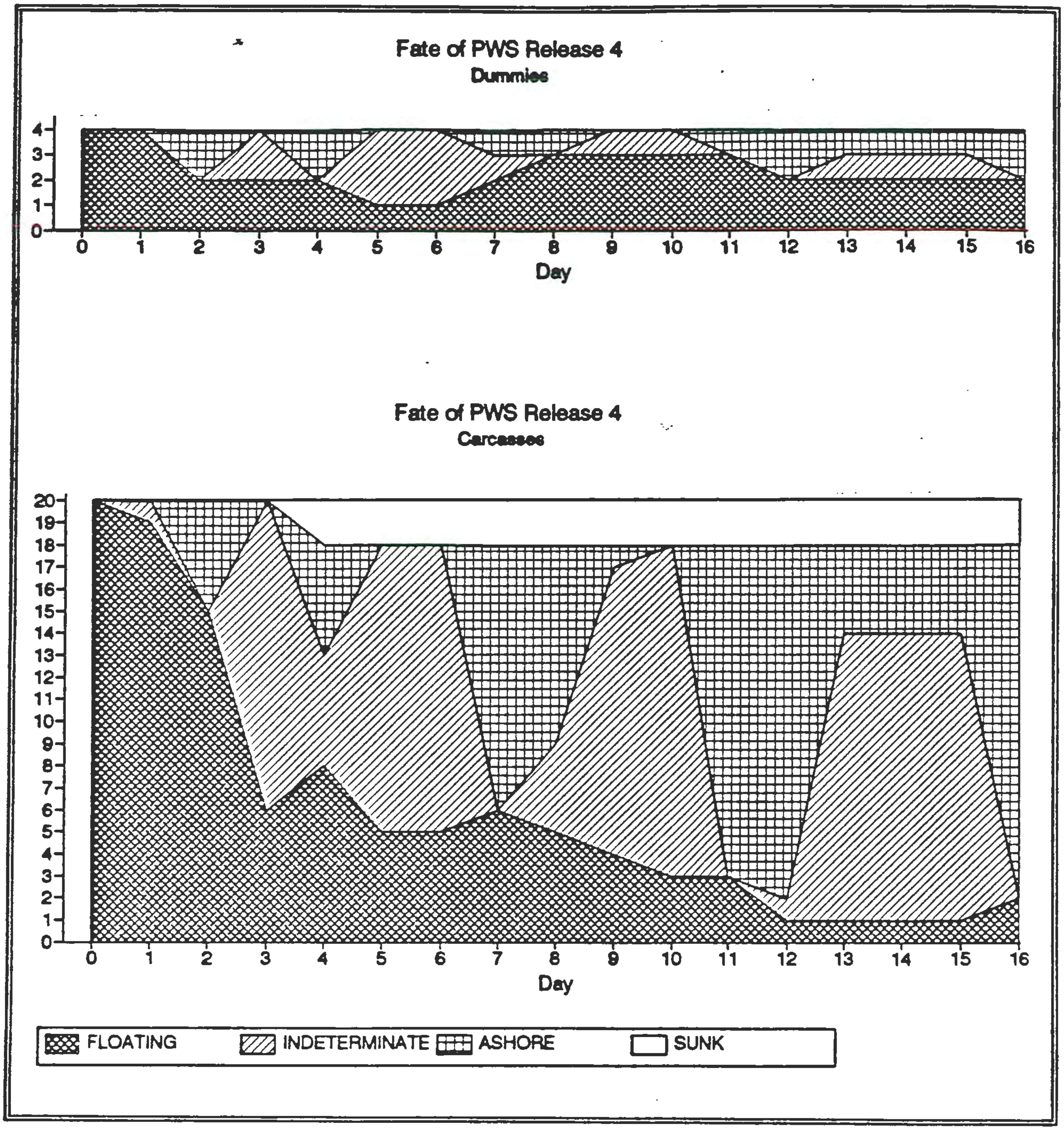


FIGURE 5-7. Fate of dummies and carcasses in Prince William Sound, Release #4. The width of each band indicates the number of carcasses or dummies in each state. The indeterminate state applies to carcasses or dummies between dates on which their status was known to have changed (table 5-7). Reflotation of both dummies and carcasses occurred frequently with this release. One of the tags still floating at the end of this release apparently never beached, and was probably attached to an intact carcass. The other had been ashore and was probably no longer attached to a carcass.

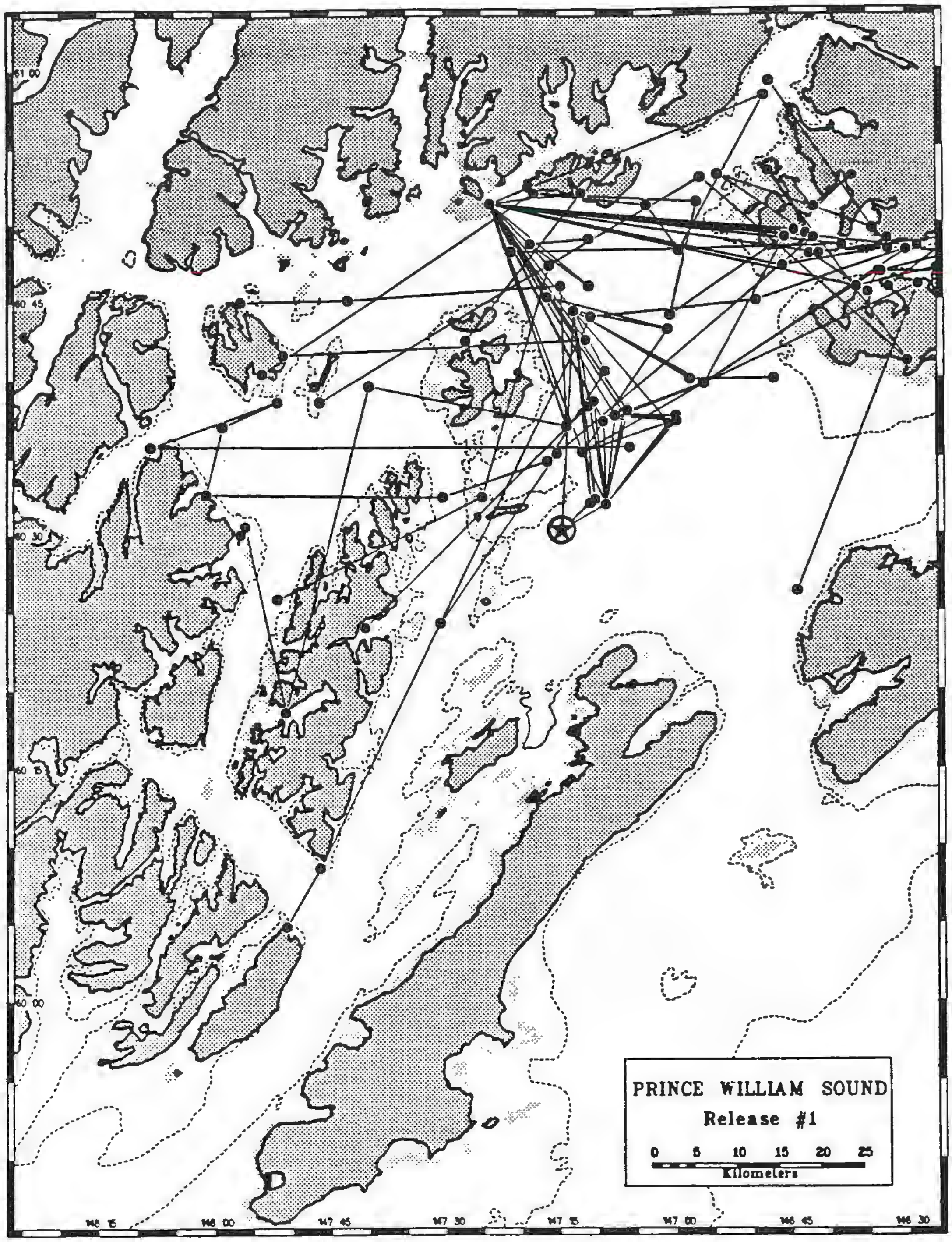


FIGURE 5-8. The movement of individual radio-tagged carcasses and dummies from Release #1. Each filled circle represents one fix; sequential fixes are connected by fine solid lines. These lines provide only a means to visualize the movement patterns and do not imply the actual route of the transmitter. The initial release point, located east of Smith Island near the center of the map, is marked by a star.

elapsed between releases AK1 and AK2, nearly all carcasses and dummies remained close together and drifted west to beach or float near Eleanor, Ingot, and northern Knight Island (figure 5-9).

Release AK3, consisting of Common Murres, was tracked for 21 days, at which time the number that had sunk or been scavenged at sea represented only 10 percent of the total (figure 5-6). AK3 was released in Montague Strait, and most carcasses and dummies drifted in a northeasterly direction where many beached on Green Island (figure 5-10). Release AK4, consisting of ducks and cormorants, was tracked for 17 days, at which time sinking or scavenging at sea had taken about one-fourth of the total, and less than 12 percent of the number released were still afloat (figure 5-7). Release AK4 was made near Glacier Island in the northernmost part of the Sound to provide a maximum expanse of open water in which they could drift. However, almost all carcasses and dummies were rapidly carried southwest into Knight Island Passage where most beached (figure 5-11). Combined, releases AK3 and AK4 had a median persistence time of 15-18 days.

5.1.3.1.2 Kodiak and the Gulf of Alaska

Completion of work in the Gulf of Alaska was more straightforward because the carcasses were released in a greater expanse of open water and only a few radio tags beached. Here, each release consisted of the same number of birds (18 Common Murres and 9 Crested Auklets), and all four releases were made in the same general area north and east of Kodiak Island. On 20 tracking flights conducted from 11 July through 31 August 1990, we recorded more than 900 position fixes of free-drifting carcasses and dummies. Only two carcasses and eight dummies beached during this phase of the study. The difference in the beaching rate suggested that, as carcasses began to sink, they were less subject to onshore winds than dummies. The results clearly indicated that conditions in the Gulf of Alaska, probably higher winds and seas, shortened the persistence time relative to the more sheltered waters of Prince William Sound. Of the 108 radio-tagged carcasses released in the Gulf of Alaska, 5 drifted out of range and 10 were still afloat when we terminated the field work. None of the 36

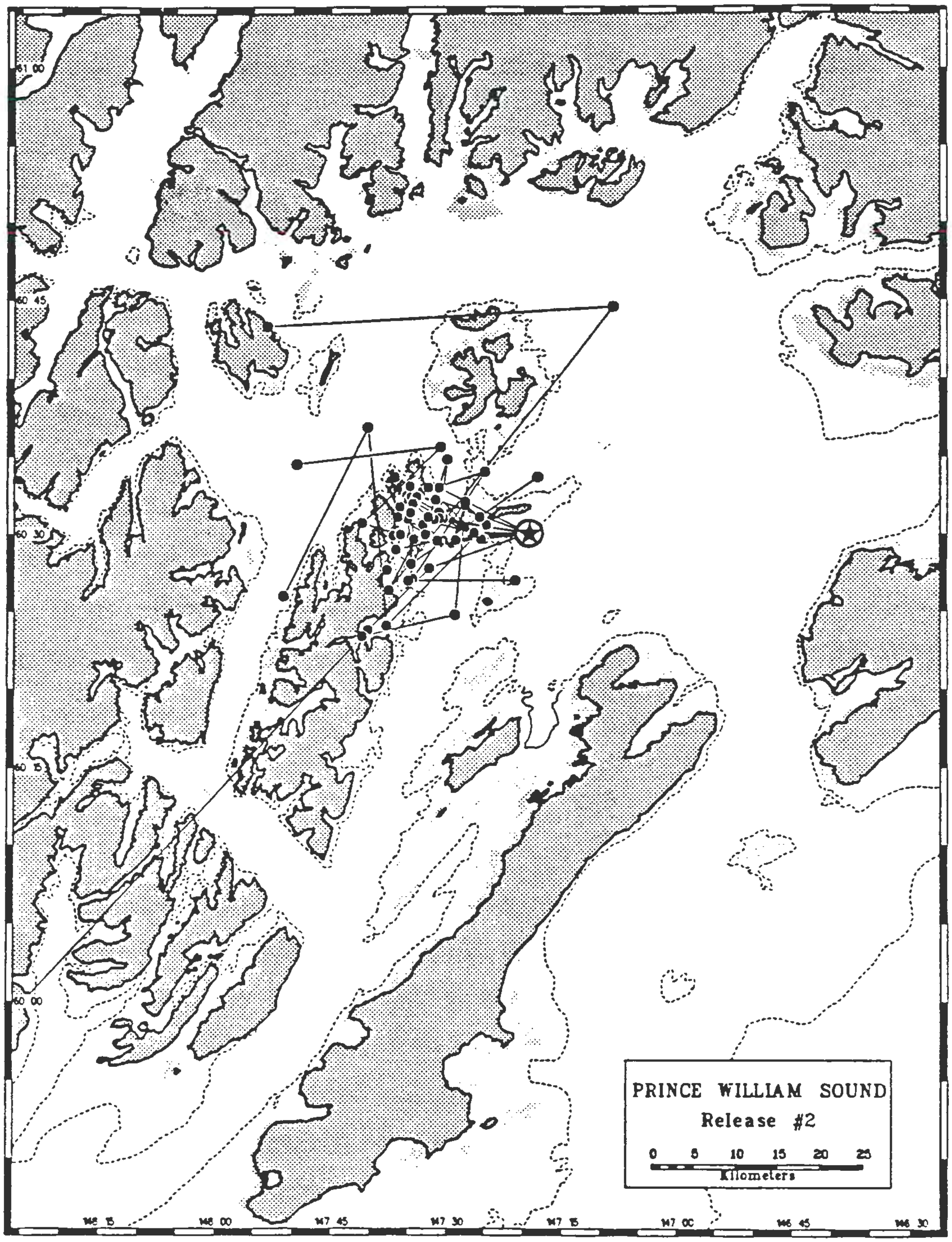


FIGURE 5-9. The movement of individual radio-tagged carcasses and dummies from Release #2. Each filled circle represents one fix; sequential fixes are connected by fine solid lines. These lines are meant to provide only a means to visualize the movement patterns and do not imply the actual route of the transmitter. The initial release point, located southeast of Smith Island near the center of the map, is marked by a star.

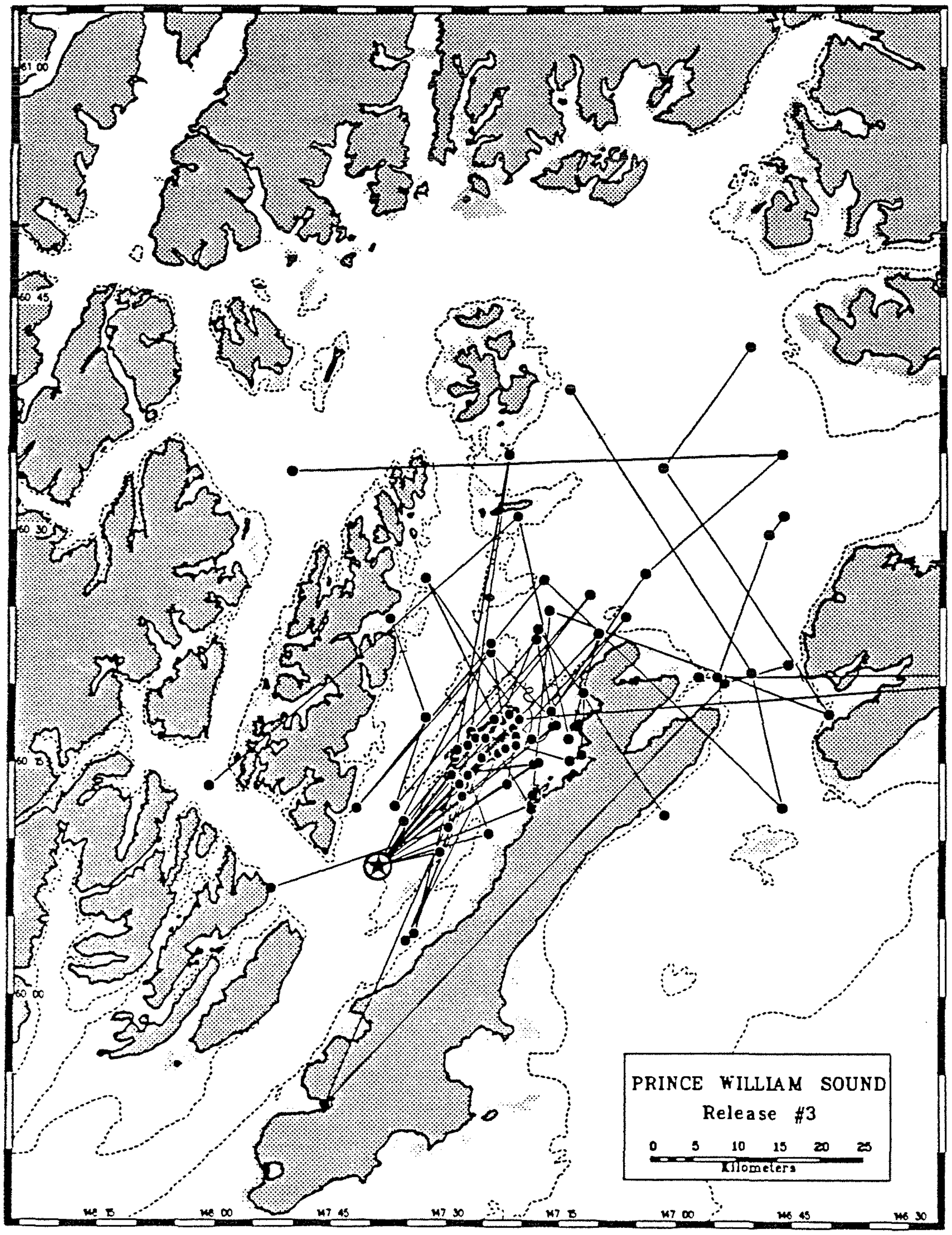


FIGURE 5-10. The movement of individual radio-tagged carcasses and dummies from Release #3. Each filled circle represents one fix; sequential fixes are connected by fine solid lines. These lines provide only a means to visualize the movement patterns and do not imply the actual route of the transmitter. The initial release point, located southwest of Green Island, is marked by a star.

FIGURE 5-11. The movement of individual radio-tagged carcasses and dummies from Release #4. Each filled circle represents one fix; sequential fixes are connected by fine solid lines. These lines provide only means to visualize the movement patterns and do not imply the actual route of the transmitter. The initial release point, located south of Glacier Island near the north end of the map, is marked by a star.

dummies was lost. The duration of the tracking period and median persistence time for each Gulf of Alaska release is shown in table 5-6. Median persistence time was only 7 to 11 days on the first three releases (AK5 through AK7), while that of the last release was similar to that found in Prince William Sound. Few carcasses from release AK5 were lost during the first week but, subsequently, numbers declined rapidly and all were sunk by day 16 (figure 5-12). Median persistence time for AK5 was 11 days. During the first week, conditions in the Gulf were fairly mild with 15 to 20 knot (kn) winds. However, during the second week following release AK5 as the seas increased under 20 to 30 kn winds, the most sinking occurred. Release AK6 carcasses also floated for the first week, but within a day or two, 80 percent were lost to sinking (dummies were still floating). This loss occurred during the same period of 20 to 30 kn winds to which the AK5 carcasses were subject. A few Common Murre carcasses from AK6 continued to float for another week (figure 5-13). Median persistence time for AK6 was only 7 days. For AK7, some loss due to sinking was recorded within 2 to 3 days following release despite relatively mild sea conditions. The rate of decline was quite uniform for this release, with about one-third of the carcasses gone by the end of the first week and another one-third gone in the second week (figure 5-14). Winds gradually increased over the tracking period from 15 to 30 kn. Median persistence time for AK7 was 9 days. Winds were somewhat calmer for release AK8, with winds of 15 to 20 kn increasing to 20 to 25 kn over the duration of the tracking period. These carcasses were all accounted for until day 10, after which 63 percent were lost in the next week due to sinking; some were still afloat when we terminated the field phase of work in the Gulf (figure 5-15). Median persistence time for AK8 was 18 days.

5.1.3.2 Statistical Differences Among Releases

The statistical treatment of data collected in Prince William Sound differed from that of the Gulf of Alaska because the beaching rate was so great. This beaching rate was simply due to the presence of many islands, coves, and points of land in Prince William Sound that snared drifting carcasses and dummies. Of the 76 carcasses released in the Sound, only 4 (18 percent) were known to have sunk (most of the rest beached, but a few from later releases

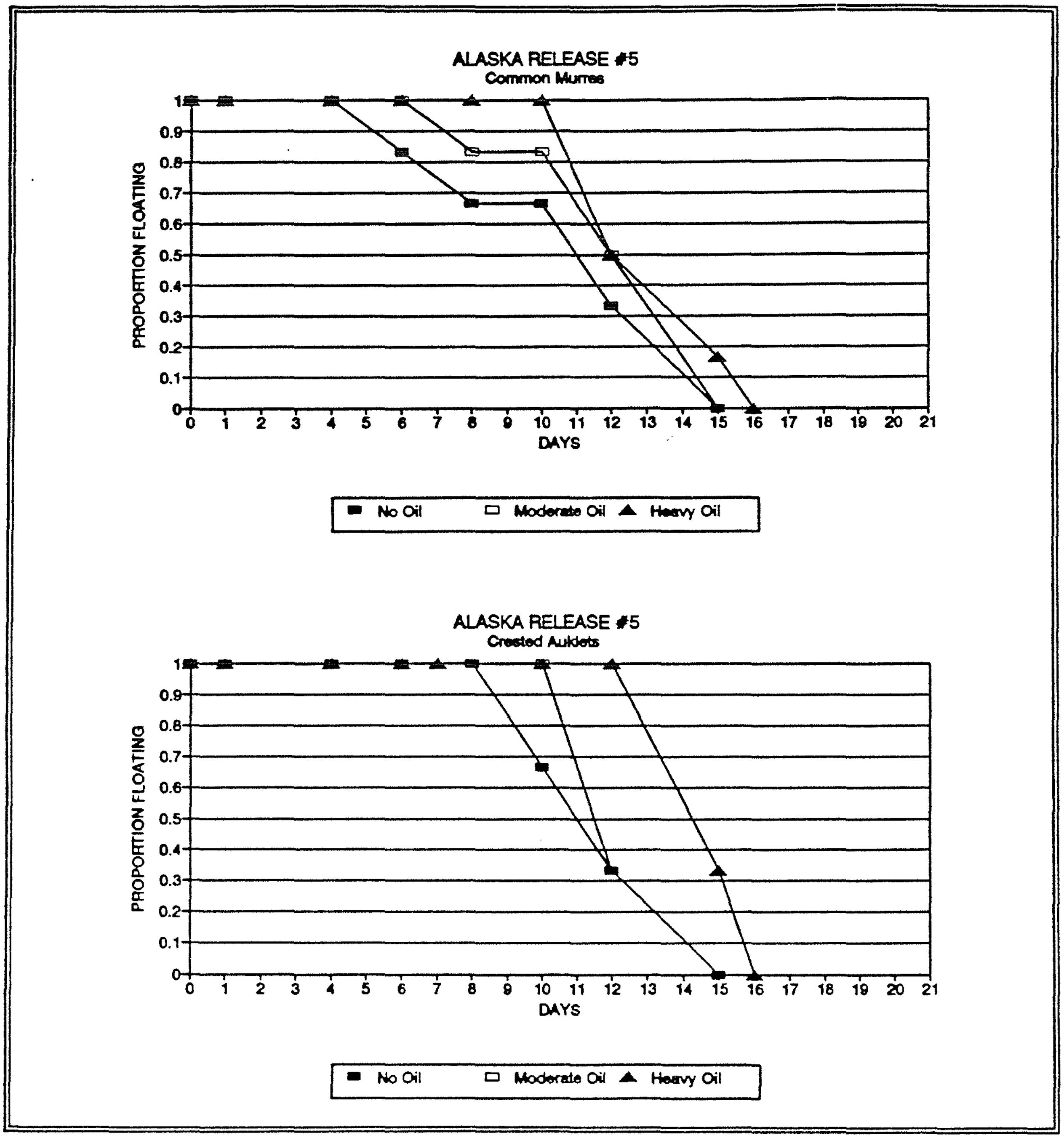
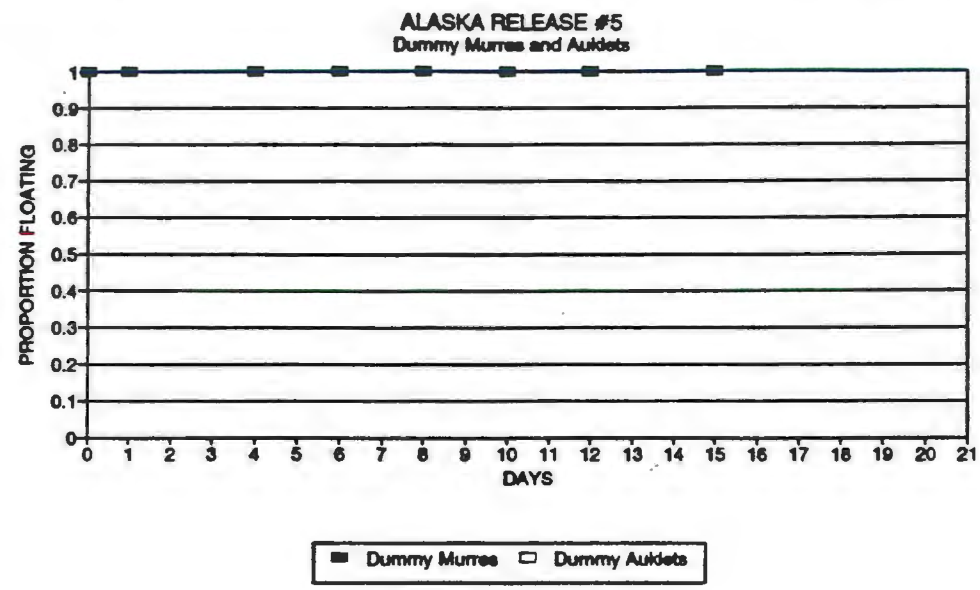


FIGURE 5-12. The proportion of carcasses and dummies that were still floating for release AK5 through time. Proportion floating is defined as the number floating divided by the number sunk plus the number floating. Beached birds and dummies are not considered. The first two graphs show the data for Common Murres and Crested Auklets, respectively, broken down by degrees of oiling. The second two graphs show the data for dummies and a breakdown of the entire release by species. Data points indicate days on which flights were made to check for transmitter signals.



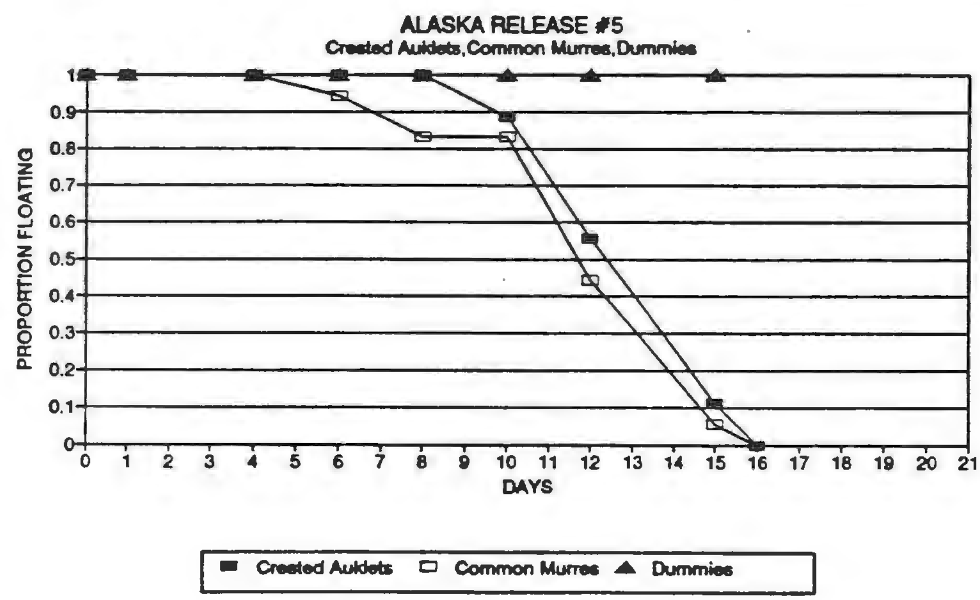


FIGURE 5-12. (cont'd.)

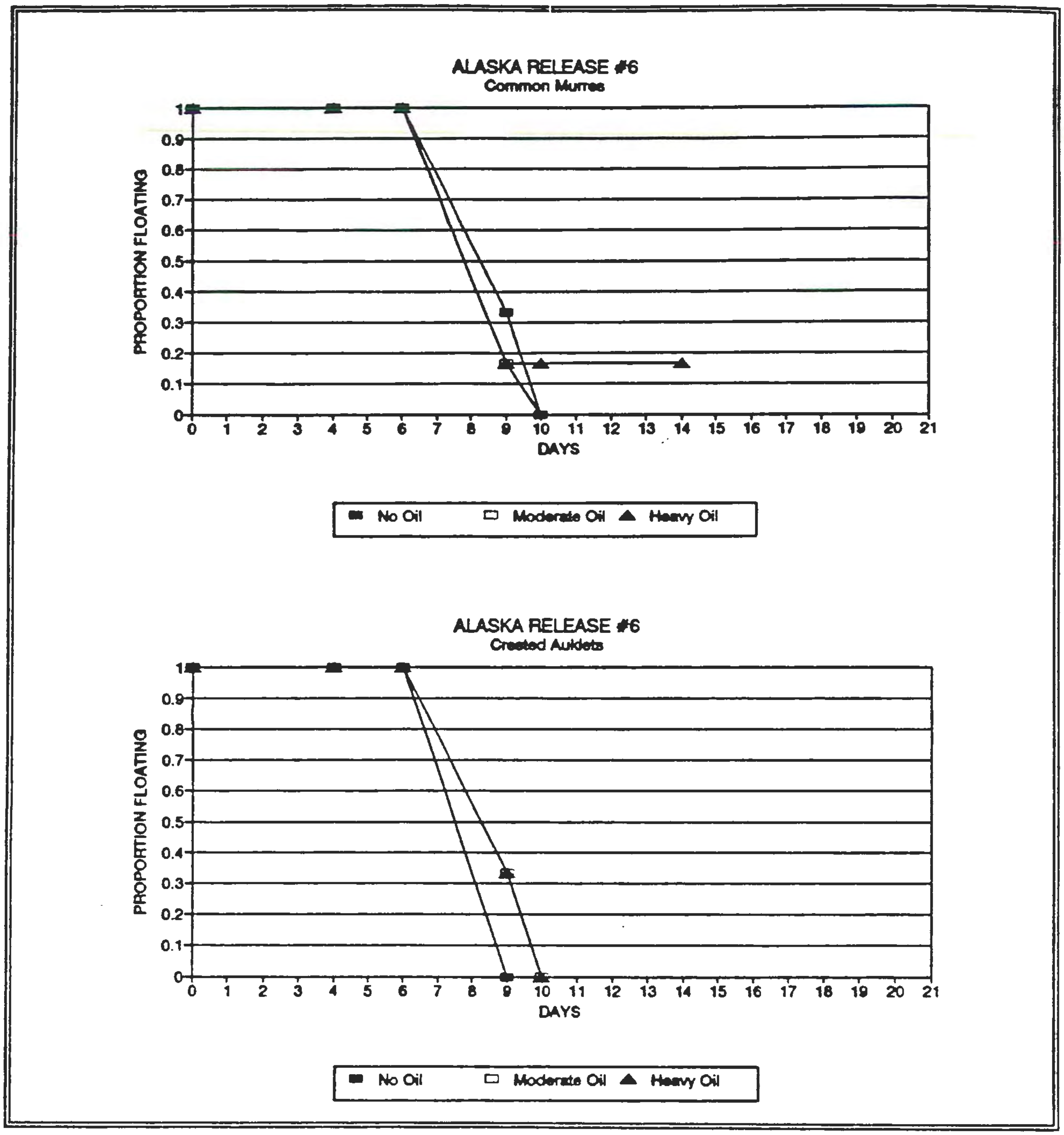
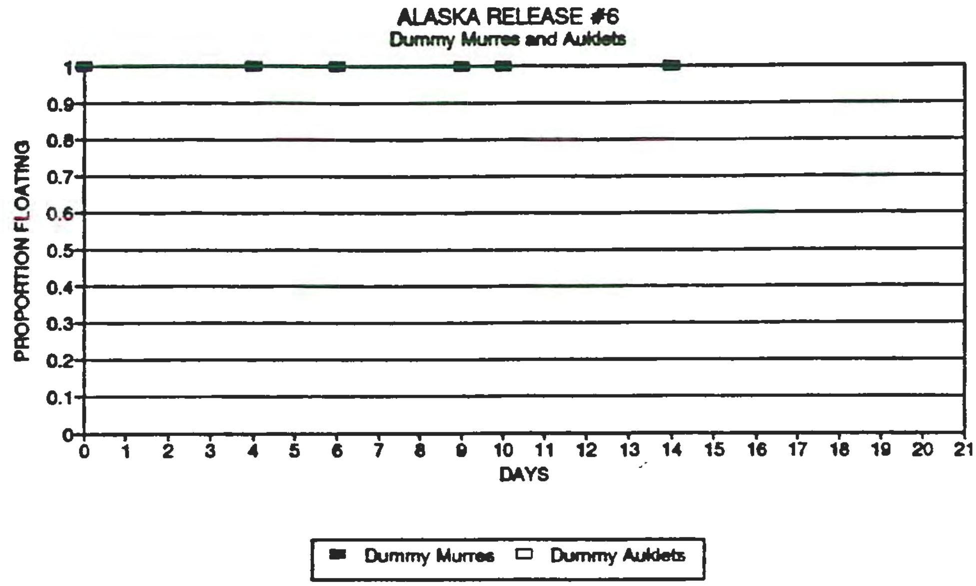


FIGURE 5-13. The proportion of carcasses and dummies that were still floating for release AK6 through time. Proportion floating is defined as the number floating divided by the number sunk plus the number floating. Beached birds and dummies are not considered. The first two graphs show the data for Common Murres and Crested Auklets, respectively, broken down by degrees of oiling. The second two graphs show the data for dummies and a breakdown of the entire release by species. Data points indicate days on which flights were made to check for transmitter signals.



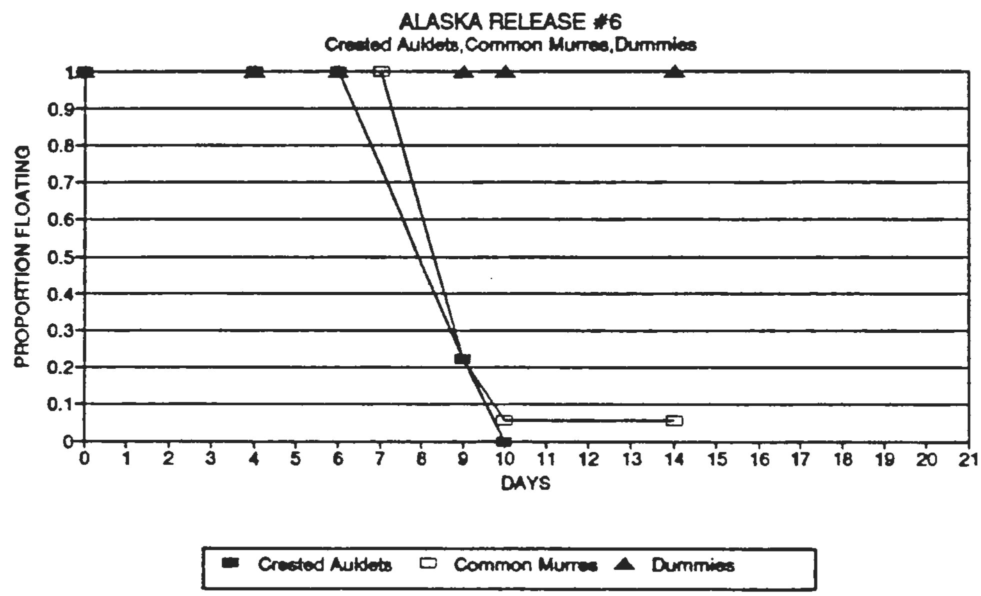
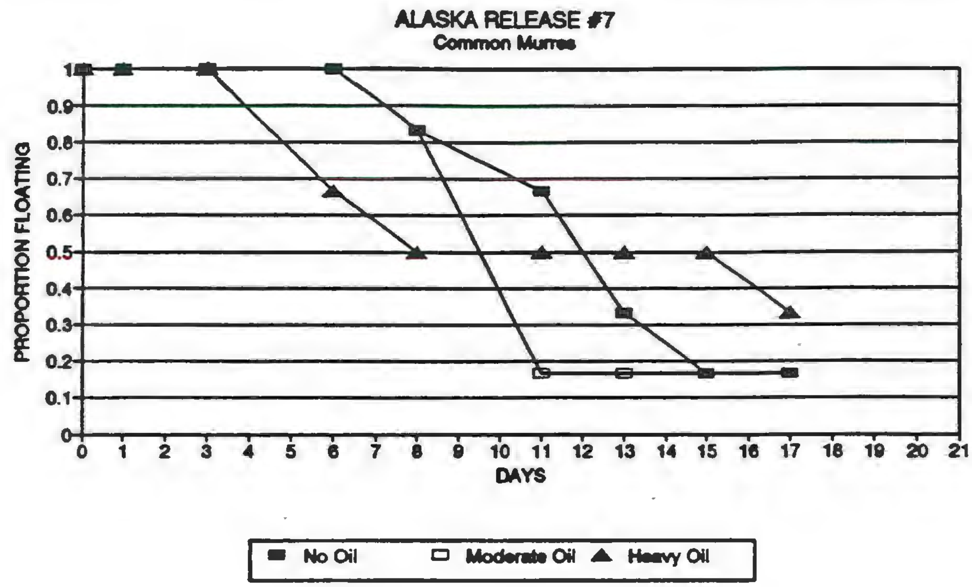


FIGURE 5-13. (cont'd.)



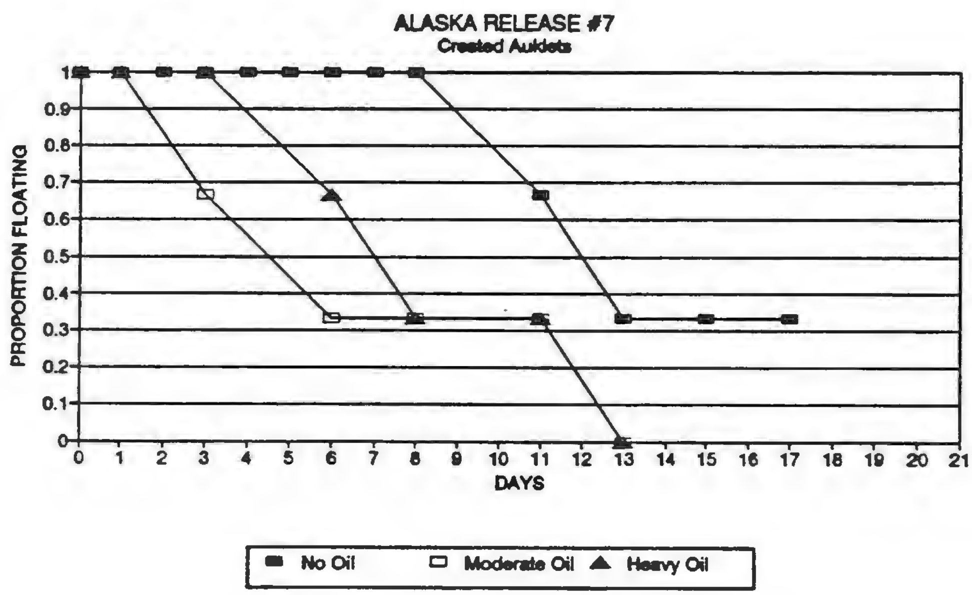
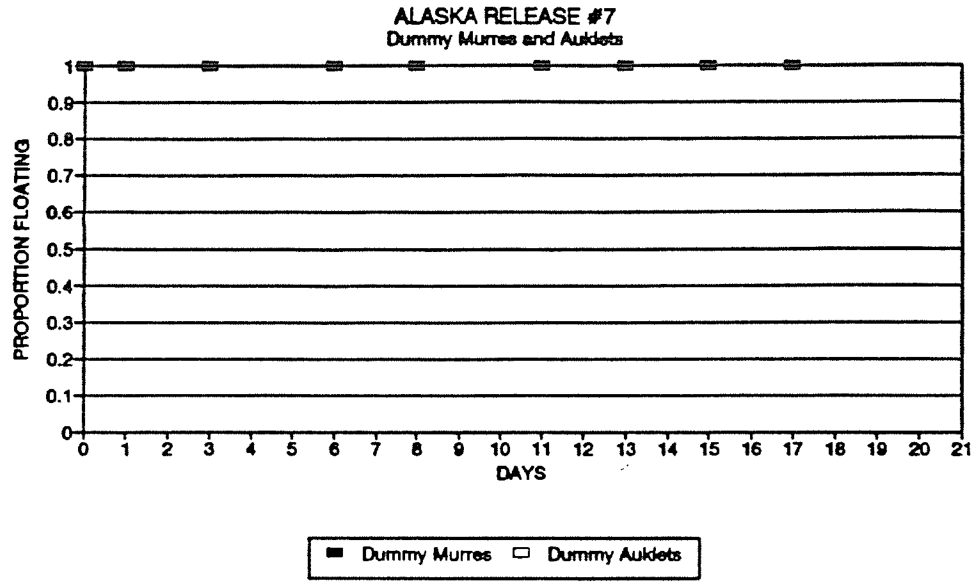


FIGURE 5-14. The proportion of carcasses and dummies that were still floating for release AK7 through time. Proportion floating is defined as the number floating divided by the number sunk plus the number floating. The first two graphs show the data for Common Murres and Crested Auklets, respectively, broken down by degrees of oiling. The second two graphs show the data for dummies and a breakdown of the entire release by species. Data points indicate days on which flights were made to check for transmitter signals.



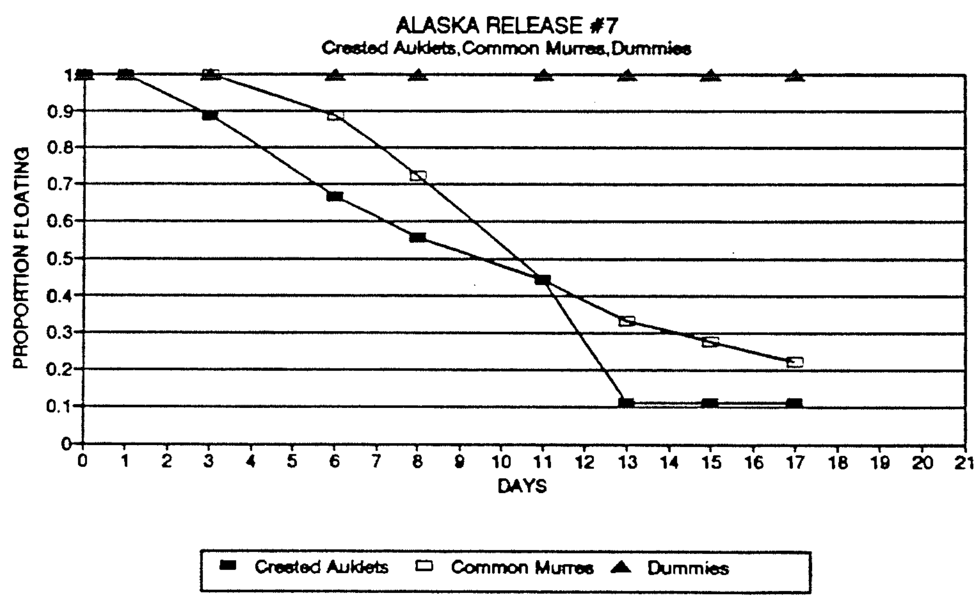


FIGURE 5-14. (cont'd.)

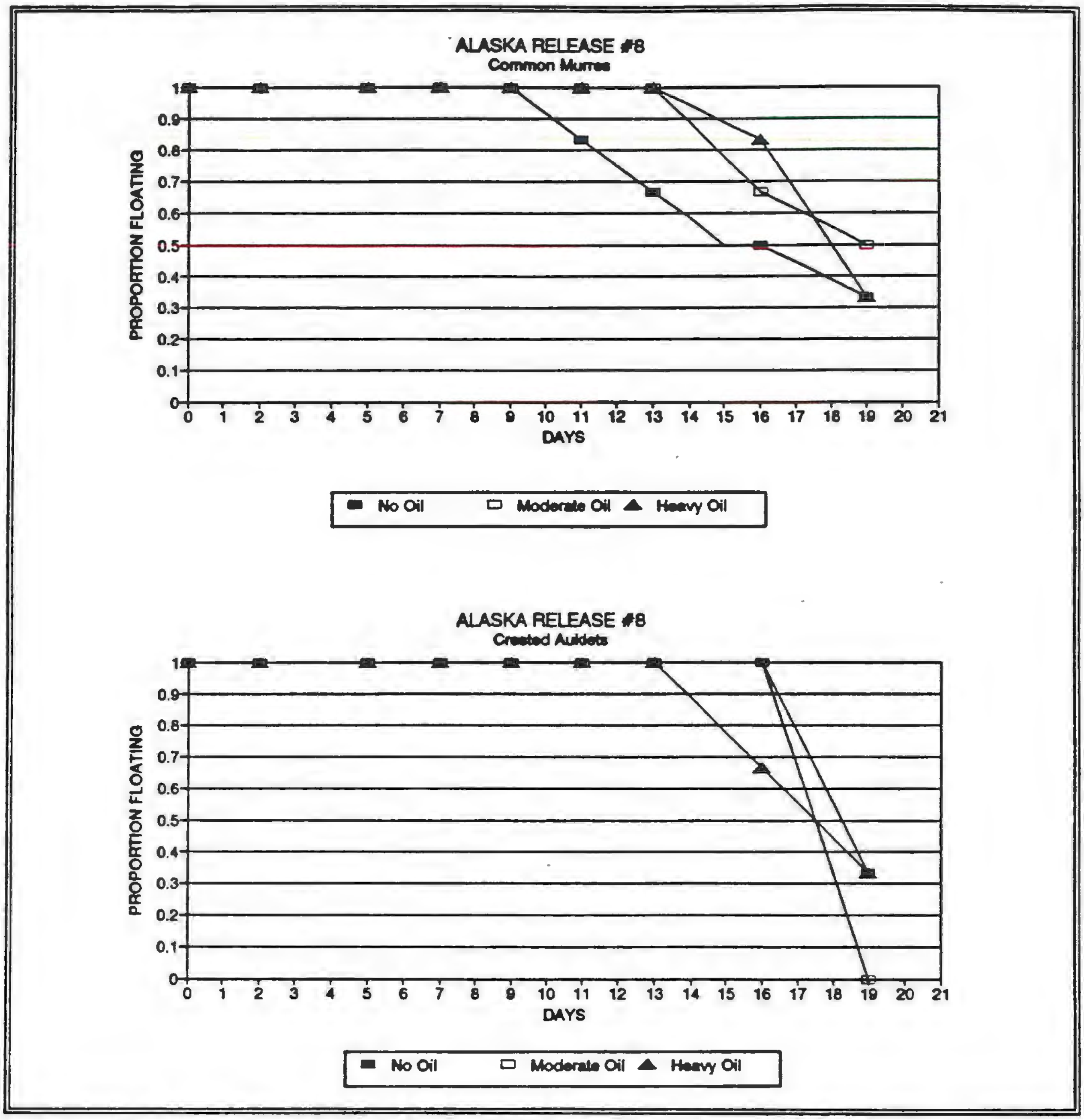
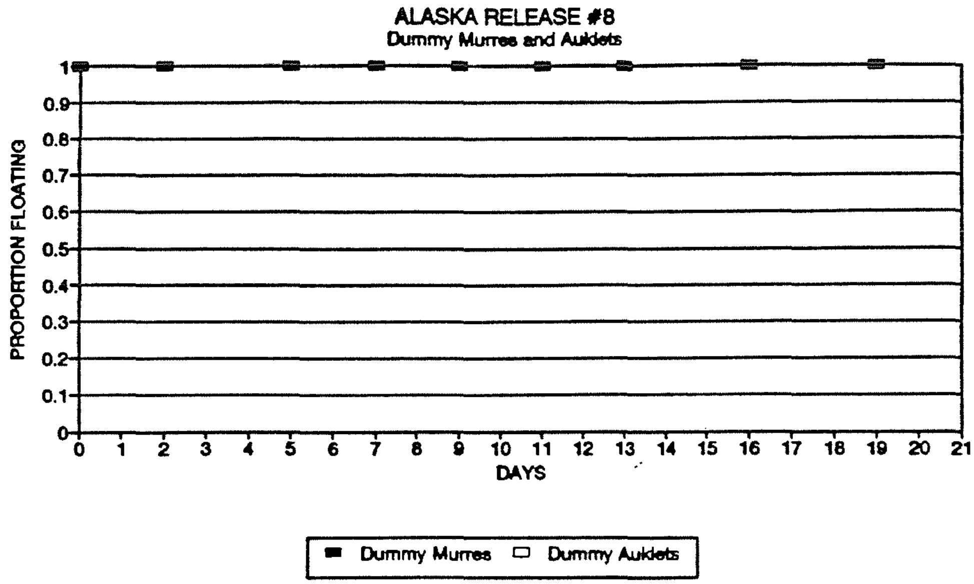


FIGURE 5-15. The proportion of carcasses and dummies that were still floating for release AK8 through time. Proportion floating is defined as the number floating divided by the number sunk plus the number floating. The first two graphs show the data for Common Murres and Crested Auklets, respectively, broken down by degrees of oiling. The second two graphs show the data for dummies and a breakdown of the entire release by species. Data points indicate days on which flights were made to check for transmitter signals.



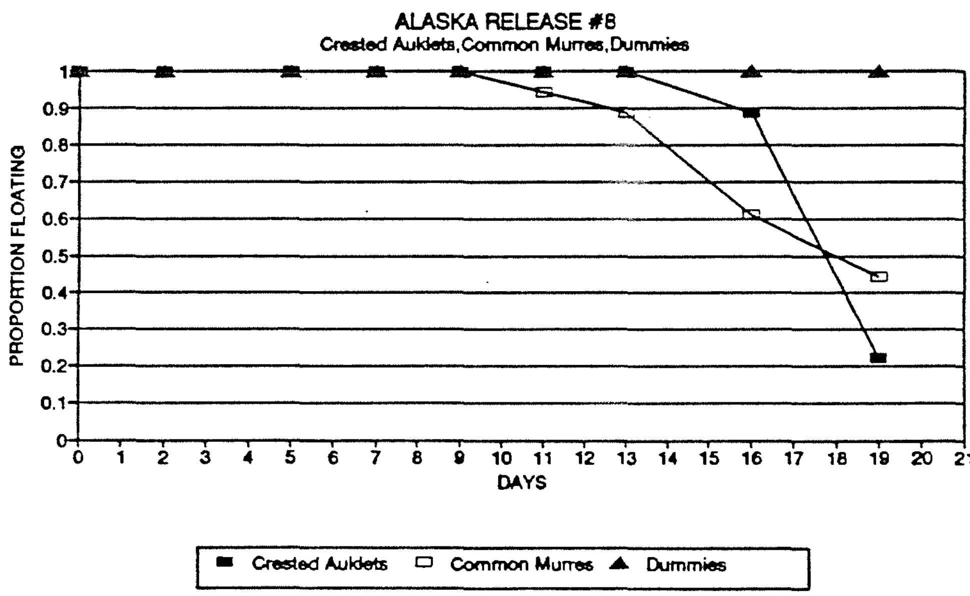


FIGURE 5-15. (cont'd.)

were still floating at the end of the study). For analysis of persistence times, we used a nonparametric technique that takes censored observations (carcasses that were beached or were still floating on the last sampling date) into account (Gehan's Test; Gross and Clark, 1975). Due to the small number of carcasses that sank, we combined releases AK3 and AK4 for this analysis. Three pairwise tests were conducted (the alpha was adjusted to preserve an experiment-wise Type I rejection rate of 0.05 (see Sokal and Rohlf, 1981, pp. 241-242). No significant differences were found in the persistence time in any comparison of releases in Prince William Sound (all $P > 0.40$).

We then used the same test to examine persistence times for the Prince William Sound data relative to the Gulf of Alaska data. Here, we combined Prince William Sound releases AK1 to AK3, for comparison with Gulf of Alaska releases: (1) AK6, which had a significantly shorter mean persistence time than all other Gulf of Alaska releases (see below), (2) AK8, which had a significantly longer mean persistence time than all other Gulf of Alaska releases, (3) AK5 and AK7, which had intermediate persistence times and did not differ significantly from each other, and (4) AK5 to AK8 combined. Prince William Sound release AK4 was excluded from these tests because, unlike all other releases, it did not involve alcid carcasses. Again, we adjusted the critical value for these tests to preserve an alpha of 0.05 for comparison of the Prince William Sound persistence data with that from the Gulf of Alaska. The Prince William Sound data was not significantly different from Gulf of Alaska release AK8 ($P = 0.09$). However, the Prince William Sound carcasses did show a significantly longer persistence time than (1) the release AK6 carcasses ($P \ll .0001$), (2) the release AK5 and AK7 carcasses ($P < .0001$), and (3) all of the Gulf of Alaska carcasses combined ($P < .0001$).

An important question that we needed to address was how oiling affects the length of time a carcass will remain afloat. For simplicity, we examined data collected from releases AK5 through AK8 in the Gulf of Alaska (these releases were the most consistent in terms of the degree of oiling). The dependent variable, persistence time, was defined as the number of days from release to sinking, where the date of sinking was considered to be the midpoint between the last signal acquisition and the next day of unsuccessful search. Examination of the data showed that a significant degree of non-normality ($P<.001$, Kolmogorov-Smirnov Test) could not be corrected for all samples by transformation. Also, the data were heteroscedastic ($P = .004$, Bartlett's Test). Although Bartlett's Test is sensitive to non-normality, we obtained the same results when we tested only those samples that were approximately normal. Thus, in a two-way analysis of variance (ANOVA), we used the ranks of persistence time, a technique known to give robust results when the assumptions of ANOVA are not met (Conover, 1980). However, the same results were obtained when we performed an ANOVA with the raw data. We chose to treat Release as a fixed factor because of the way release times and locations were selected; however, treating it as a random factor would not have significantly changed the results of the ANOVA. As expected, we found that the length of time carcasses remained afloat did differ significantly from release to release ($P<.001$; table 5-8). Releases AK5 and AK7 were similar in regard to persistence time, but release AK6 was significantly shorter and AK8 was significantly longer. (Tukey, multiple comparison test with alpha = 0.05). However, the presence of oil (moderate or heavy) did not have a significant effect on the length of time carcasses remained afloat ($P>0.5$; table 5-8). Even for the data showing the greatest tendency for persistence time to increase with degree of oiling (releases AK5 and AK8), the effect of oiling was not significant. Using a two-way ANOVA, we then tested for any species differences in persistence time for Common Murres and Crested Auklets in Gulf of Alaska releases (AK5 through AK8). Release was included in this model because it was shown in the first analysis to be significant. Persistence times of the different species were not significantly different ($P>0.90$; table 5-9). A three-way ANOVA examining release, species, and degree of oiling gave identical results, and no additional interactions were significant.

5.2 Bird Carcass Search Effort

A key determinant of the proportion of oiled birds retrieved is the level and distribution of the search effort. In the weeks after 24 March 1989, an effort was made to collect oiled birds along the coastline of Prince William Sound and the Gulf of Alaska. This effort was

TABLE 5-8. Two-way fixed factor ANOVA of persistence time by release and degree of oiling.

SOURCE	df	MS	F	P
Release	3	5241	2.2	<.001
Oiling	2	155	.65	.52
Interaction	6	143	.60	.73
Error	60	237		

TABLE 5-9. Two-way fixed factor ANOVA of persistence time by release and species.

SOURCE	df	MS	F	P
Release	3	18793	42.1	<.001
Species	1	6	.01	.91
Interaction	3	495	1.1	.35
Error	100	446		

based on three motivations: (1) to prevent secondary poisoning of wildlife that would otherwise scavenge oiled carcasses on shorelines; (2) to collect live oiled birds for cleaning, rehabilitation, and release back into the wild; and (3) to document the occurrence of direct damage to wildlife. The bird recovery effort was not designed to search shorelines systematically so that an estimate of the total bird mortality could be subsequently made. Bird search and rescue crews did not emphasize the importance of collecting detailed information on the amount and type of shoreline searched and other measures of effort (e.g., time spent) so that the shoreline coverage could later be estimated. The boats engaged in the search effort (catcher boats) seem to have had no clear understanding of the need for information on their effort. Records of catcher boats vary greatly in their descriptions of work accomplished, and most do not specify which shorelines were searched on a given day, the type of substrate searched, or the amount of time spent searching for oiled birds. We do know that the search effort was uneven. In some cases, beaches were searched diligently and often; others were not searched at all.

This section attempts to quantify, from the limited data that are available, the more significant components of the bird search effort: the proportion of shoreline searched, the interval between arrival of oiled bird carcasses on shorelines and the search, and the frequency of searches.

5.2.1 Sources of Information

The information used in this section is derived from personal accounts of individuals who were involved in 1989 in the cleanup or wildlife damage assessment along different sections of oil-affected coast from Prince William Sound to the Alaska Peninsula.

Microfilmed records of field notes, ship logs, radio dispatches, instructions to search and rescue crews, trip reports of Department of the Interior personnel to oil-impacted areas, and reports of agency biological investigations were provided by USFWS. Follow-up interviews were conducted in January 1991 with individuals to whom the microfilm records refer and with individuals known to have been in the field in 1989 (mostly National Park or USFWS personnel, but including one Veco catcher boat coordinator). Those interviewed were asked to provide the following information, based on their personal knowledge of the bird search and rescue effort along the section of coast in which they worked: the amount of shoreline that was sandy and walkable or rocky and difficult to search; the proportion of coastline searched, either by agency personnel or catcher boats under contract to Exxon; the frequency of searches by type of shoreline; and, if observers were present when carcasses began to arrive, the interval between the arrival of oil and oiled birds on a section of shoreline and the time the shoreline was first searched. Accounts were obtained from representative sectors of affected coastline: Prince William Sound, the Kenai coast, the Barren Islands, Katmai National Park, Becharof National Wildlife Refuge, Aniakchak National Monument, Kodiak Island, and other parts of the Alaska Peninsula National Wildlife Refuge (NWR) (sectors are shown in figure 4-6).

Copies of unpublished trip reports and reports of more extended field investigations were also obtained from National Park Service (NPS) and USFWS regional and field offices. Sources in parentheses in the following section refer to telephone interviews conducted with the individuals concerned.

5.2.2 Results

Table 5-10 quantifies and summarizes the results of eyewitness accounts of bird search and rescue effort by coastline sector—Prince William Sound, Kenai Peninsula, Barren Islands, Katmai National Park, Becharof NWR, Aniakchak National Monument, Alaska Peninsula NWR, and Kodiak Island. Appendix C presents the sources of information from which the quantified contents of the cells in table 5-10 were obtained. The search effort data are regarded as either spatial (related to the proportion or extent of rocky versus sandy shoreline types searched) or temporal (related to the timing of the initial shoreline search and the frequency of subsequent searches).

5.2.2.1 Spatial Considerations

All sources agreed that shorelines consisting of sand, gravel, and small cobble are more easily walked than rocky shorelines or shorelines with larger cobble and boulders. Large cobble or boulder shorelines are traversed only slowly, painstakingly, and with some risk. Also, oiled dead birds in crevices between boulders are not visible from a distance as are those lying in sand, gravel, or small cobble beaches. We asked agency personnel familiar with portions of shoreline for which they had administrative jurisdiction, who were either involved with the bird search and rescue effort or at field camps in 1989, to quantify the relative proportions of walkable versus unwalkable beach types in the areas with which they were familiar. In addition, quantitative data were available for the Barren Islands and Becharof/Alaska Peninsula NWR coastlines from unpublished USFWS reports (references listed below).

Table 5-10. Summary of search effort data derived from microfilm and other documentary materials, unpublished reports, and telephone interviews.

Section of Coast	Time Lag of Initial Search (Days)	Shoreline Type: Sandy or Walkable — Percent of Total	Percent Searched	Mean Search Interval (Days)	Shoreline Type: Rocky or Difficult to Walk — Percent of Total	Percent Searched	Mean Search Interval (Days)
Prince[1] William Sound	6-16[2]	85-95	70-100[3]	3.5[4]	5-15	50-95[3]	3.3[4]
Kenai[5] Fjords Area	6-20[6]	10-20	100	7-11[7]	80-90	10[8]	?
Cook Inlet	?	?	?	?	?	?	?
Barren[9] Islands	2[10]	13	100[10]	7.5[10]	87	0	0
Katmai NP	8-15[11]	25[12]	70-90[13]	7-9[14]	75[11]1	10-20[11]	0-30[11]
Becharof[15] NWR	7-15[15]	30	90	30-45	70	0-15	Once per summer[15]
[Puale Bay]	6	75	100	2	25	100	2
Aniakchak[16] NM	?	50	100	6-10[17]	50	100	?
Kodiak[18] Island Area	6 (Min.)	?	75 (Max.)	Variable	?	25-50[19]	Variable
Alaska[20] Peninsula NWR Area	Midsummer	45	10	Once	55	0	0

Footnotes: See Appendix C for most references.

1. All data for Prince William Sound from telephone interview with Kelly Weaverling, 1/91, unless otherwise noted.
2. Average is closer to 6 than 16, Snyder-Conn and Scannell, Microfilm 469-0583.
3. Lower values from telephone interview with David Nysewander, 1/91.
4. Our estimate - 1 to 3 times per week through 15 June.
5. Most date for Kenai Fjords from telephone interview with Bud Rice, 1/91, unless otherwise noted.
6. Lower values from Microfilm 005-1216. Our best estimate 8-10.
7. Microfilm 005-1058 to 005-1216, and Karen Jettmar trip report.
8. Microfilm 003-0004, 003-0017.
9. Date for Barren Islands from Ed Bailey trip reports.
10. Actual interval, not estimate.
11. Telephone interview with Jay Wells, 1/91, and Microfilm 001-0892,001-0898, 001-0905, 001-0912, 001-1065, 001-1448, 003-0547, 003-1201.
12. Telephone interview with Janice Meldrum, 1/91.
13. Telephone interview with Jay Wells, 1/91.
14. Telephone interview with Janice Meldrum, 1/91, and Microfilm 001-1231.
15. Data for Becharof National Wildlife Refuge, including Puale Bay, from telephone interview with Ron Hood, 1/91.
16. Most data for Aniakchak National Monument from telephone interview with Jerry Bronson, 1/91.
17. Telephone interview with Jay Wells, 1/91, and Microfilm 003-0998.
18. Data for Kodiak from telephone interview with Jay Belinger, 1/91.
19. Microfilm 003-0004, 003-0017, 003-0998. Estimate based on weather conditions.
20. Most data for Alaska Peninsula National Wildlife Refuge from telephone interview with Donna Dewhurst, Jay Bellinger 1/91.

The relative proportions of the two shoreline types were estimated by coastline sector (table 5-10). Estimates of walkable, relatively easy-to-search shorelines varied from as high as 85 percent in Prince William Sound to a low of 13 percent at the Barren Islands and from 10 to 20 percent along the Kenai Fjords coast. The Katmai and Becharof sectors of the Alaska Peninsula, where many of the birds were retrieved, consisted of an average of 25 to 30 percent sandy or walkable and 70 to 75 percent rocky and difficult-to-search terrain. Seventy-five percent of the shoreline at Puale Bay, which is within the Becharof NWR, consists of sandy beaches. (Because a field camp was established there on 15 June, the search effort differed from that of the rest of the Becharof NWR.) In general, rocky, difficult-to-walk coastlines predominate in the oil-affected areas, except in Prince William Sound, where much of the coastline is protected and consists of gently sloping small cobble and a few sandy beaches. A relatively small proportion (9.5 percent) of the total number of dead birds retrieved after the spill were retrieved in Prince William Sound. Sixty-four percent of the birds were retrieved from the Kodiak Island and Alaska Peninsula areas.

According to field sources, most sandy or walkable shorelines were searched (at least once) for oiled live and dead birds. Estimates of the number of walkable beaches that were searched in Prince William Sound vary from 70 percent (Nysewander) to 100 percent (Weaverling), whereas 50 percent (Nysewander) to 95 percent (Weaverling) of rocky shorelines were searched. A reasonable estimate probably lies within these intervals. Even in Prince William Sound, however, searching bouldery and rocky shorelines (e.g., on Green and Montague Islands) would have been extremely time consuming (Brian Sharp, pers. comm.).

Along the Kenai Fjords coastline, nearly all sandy shorelines were searched at least once (Bud Rice PS Wildlife Biologist); however, a maximum of only about 10 percent of rocky shoreline type appear to have been searched. The low estimate for rocky shoreline is derived from Rice's impressions from field work in 1989 skiff reports of visits to sandy beaches, and catcher boat diaries in which searching rocky shorelines is seldom mentioned. The low estimate seems reasonable, given the hazardous nature of the coastline on nautical charts and the influence of weather on the accessibility of coastline; exposed coastline would not receive the attention that protected sandy bays would receive because of the hazards involved. Instructions to catcher boat crews were, "Above all else, safety first. . . . Avoid dangerous beaches" (Veco instructions to catcher boats, Microfilm 469-0419). Such safety precautions included not walking on tidal flats, not searching away from the beaches (because of bears), and not putting ashore in Zodiac inflatable boats when seas were higher than 3 feet. References to catcher boats "going sightseeing" or "hiding out" in bays without oil (e.g., Microfilm 003-0004; 003-0017) lend further credence to low estimates of the search effort along the Kenai coast.

On the Barren Islands, all sandy beaches were searched, most of them several times; however, rocky shorelines were not searched at all (Ed Bailey, Alaska Maritime NWR Biologist, trip reports to the Barren Islands). Rocky shorelines constituted 87 percent of the total shoreline present (109 km). Of the total number of dead birds, over 2,000 or 6 percent were retrieved from the sandy beaches that were searched on the Barren Islands.

On the Katmai coast, Jay Wells, an NPS employee who accompanied the Veco catcher boats, estimates that approximately 70 percent of the sandy beaches were searched for oiled birds. Brown bears on beaches interrupted 30 percent of their searches. The inhibiting factor that brown bears presented is corroborated by Heidi Herenden, Katmai National Park, in her statement, "We do not land on bear beaches" (Microfilm 003-1154), and by fishermen who indicated a fear of brown bears. Wells stated that "some" rocky shorelines were searched, but few oiled birds were found, and searches concentrated elsewhere. A figure of 10 to 20 percent seems a reasonable estimate for the proportion of rocky shorelines searched. The portion of Katmai shoreline from the Kamishak River to Cape Douglas was not searched at all (Janice Meldrum, NPS, Kodiak).

Throughout May, the Becharof NWR coastline received considerably less search effort from the Veco catcher boats than did the Katmai coast (Donna Dewhurst, Refuge Biologist, Becharof NWR; Janice Meldrum, NPS, Operations Section Chief for Katmai coast, Kodiak). In fact, this problem gave cause for agency complaint (Jay Bellinger, Kodiak NWR Manager and Kodiak zone coordinator). It is therefore likely that less than 70 percent of the sandy beaches along the Becharof coast and a maximum of 15 percent of the rocky beaches were searched by Veco boat crews. However, at the Puale Bay and Oil Creek, the refuge had field camps that covered most of the shoreline within approximately 36 km of the camps, or 20 percent of the 153 km of refuge shoreline. It is assumed that refuge personnel searched 100 percent of both sandy and rocky coastline within striking distance of camps. In addition, refuge personnel transported to beaches by helicopter walked most of the sandy beaches, so 90 percent of the sandy beaches were estimated to have been searched. The number of rocky beaches searched is unclear; our impression is that few were searched and that 15 percent is a reasonable maximum estimate of the proportion of rocky beaches searched along the Becharof coast.

About one-half of the Aniakchak National Monument coast consists of two rather sandy bays, both of which were searched by Veco. In addition, NPS personnel stay at the Aniakchak Bay cabin for more than a month in summer. Coverage of this limited stretch of coastline thus seems to have been quite good: a safe assumption is that 100 percent of sandy beaches and perhaps close to 100 percent of rocky portions were searched. Jerry Bronson, NPS, stated that the Veco "stuck with it" insofar as rocky beaches were concerned. However, Bronson also stated that he had to rely on scavengers—eagles and bears—to direct him to oiled birds hidden between rocks on rocky beaches. Because Veco personnel did not spend the same amount of time as NPS at Aniakchak and Amber Bays, they were unable to take advantage of such clues, although Bronson presumably passed information on the positions of dead birds he located to the catcher boat crews.

The remainder of the affected portions of the Alaska Peninsula is administered by the Alaska Peninsula NWR. Coverage of this coastline was extremely low; probably 10 percent of the sandy beaches and none of the rocky shoreline were searched (Donna Dewhurst, Jay Bellinger). The sparse distribution of oiled birds along this coast may be indicative to some extent at least of limited search effort. Birds were recovered in Chignik Bay and even as far west as Perryville, where several hundred birds were retrieved in early May.

The search effort on Kodiak and Afognak Islands was apparently highly variable (Jay Bellinger) and difficult to quantify. Our impression is that a maximum of 75 percent of the sandy beaches and a maximum of 50 percent of the rocky coastline may have been searched in this area, and that a more reasonable estimate for rocky shoreline is less than these percentages.

One or two reports were made of oiled birds from Bristol Bay, presumably of birds that entered that body of water through Unimak Pass. The search effort along the Bering Sea coastline was almost nonexistent. It is surprising that any recoveries were obtained from that area.

The search effort is reflected in the number of seabird catcher boats employed in the areas coordinated by the various oil response command centers. Seward (responsible for the Kenai coast) had 40 boats under contract, Prince William Sound had 31, and Kodiak (responsible for Kodiak, Afognak, and the Alaska Peninsula) had 16 (Microfilm 469-0409 to 0413). (See table 5-11.)

TABLE 5-11. Number of catcher boats employed.

	10 MAY	2 JUN	22 JUL	AFTER 22 JUL
Prince William Sound	31	20	2	0
Seward	40	26	13	7
Homer	6	4	6	0
Kodiak	18	16	13	8
TOTAL	95	66	34	15

Dead oiled birds were also retrieved during the beach cleanup stage. However, due to the slow pace of that work, the areas covered were limited, and the number of birds was relatively small. During the cleanup stage, apparently due to confusion, some oiled birds were discarded in the oily waste and were deposited in community dumps, e.g., at Seward (Bud Rice) rather than at the established collection points (Jay Bellinger).

At three locations, large numbers of birds were burned: at Hallo Bay (Katmai coast), at least 100 birds (Kate Roney, NPS) (Microfilm 001-1162); at Gore Point (Kenai coast), 600 birds (Karen Jettmar); and at Afognak, "a huge mass" (Janice Meldrum). These birds also were not included in morgue totals.

Helicopters were used on the Alaska Peninsula to direct the effort of catcher boats to areas where numbers of dead birds were seen (Ron Hood, Janice Meldrum). It is not known to what extent the efficiency of the search effort was thereby increased on rocky shores.

Little quantified information is available that can be used to determine whether the deposition and recovery rates of oiled birds differed on rocky versus sandy shorelines. There are many observations of oiled birds on sandy beaches and in bays, but few references to oiled birds retrieved from rocky shorelines. In 1990 (this study), in Prince William Sound, six of nine birds with transmitters were recovered from rocky beaches, and it appears that oiled birds were recovered in more or less equal proportions on all shorelines regardless of type (Kelly Weaverling). Along the Kenai coast, oiled birds were observed lodged in crevices between rocks at Black Bay (Bud Rice). Along the Katmai coast, Jay Wells stated that few oiled birds were recovered along rocky shorelines that were searched, and that oiled birds tended to be found in higher concentrations in specific portions of bays, i.e., in southwest corners where sandy and rocky shorelines met (Jay Wells). Reduced visibility on rocky shorelines probably lowered recovery rates sharply, but the extent of the reduction is unknown. One method for testing whether or not deposition of carcasses varied with shoreline type in a consistent fashion would be to compare the coastal classification maps (ESI data) with mapped data showing oil deposition. This analysis cannot be carried out until final mapped data showing oil distribution become available.

In summary, it appears that the search effort was greater in Prince William Sound, where a relatively high proportion of the shoreline was searched, than along the Kenai coast, the Barren Islands, or the Alaska Peninsula. The latter are more rugged, with a greater proportion of difficult-to-walk shoreline, and are more remote. The lowest number of oiled dead birds was retrieved from Prince William Sound despite its relatively greater accessibility. The highest number was retrieved from the Alaska Peninsula, despite the lower search effort (measured in spatial terms as the proportion of the coastline searched) in that area. Rocky, difficult-to-walk shorelines were not searched with the same intensity as easily walked, sandy beaches, and much of the search effort was apparently conducted from skiffs rather than by walking over boulders (Jay Bellinger). Dead birds in crevices would not be visible from boats, nor would they be visible even by walking over the rocks, unless the path of the observer came close to the bird.

5.2.2.2 Temporal Considerations

Two temporal components of the search effort influence the proportion of birds recovered: (1) the interval between the arrival of oiled birds on a particular beach and the first bird search and pickup on that beach and (2) the interval between searches of a given beach.

In most areas, the arrival of the first oil and oiled birds on particular shores is not known precisely. However, the administrative delay in mobilizing for the emergency is well known. The interval between the arrival of oil and the first bird collections is given by many observers as a minimum of 6 days for those beaches that were searched first. For reasons discussed below, the interval was longer than that for those shorelines searched later. Table 5-10 presents data for a sample of shorelines for which the dates of arrival of oil/oiled birds and the dates of first response are known.

For Prince William Sound, mobilization of the "full complement" of catcher boats took 6 days (Kelly Weaverling, Bird Rescue Coordinator, Cordova), but one shoreline did not seem to have been searched 16 days after the spill (Microfilm 469-0583). At Kenai Fjords, some shorelines, e.g., in the Pye Islands and at Gore Point, where large numbers of oiled birds were being found, were searched within 6 to 10 days after the arrival of oil (Microfilm 005-0726), but Bud Rice (NPS) recounts that a beach at Bear Glacier was not searched until May 10, i.e., 20 days after the arrival of oil on or about April 20. The sandy beaches of the Barren Islands were first searched on April 14, which was just 2 days after the arrival of oil. This delay is the smallest recorded for any sector. Along the Alaska Peninsula, typical minimum response times seemed to be consistently 6 to 7 days, but a time lag of 15 days at Katmai was indicated, assuming an oil arrival date of April 22. On Afognak Island, the minimum response time was 6 days, but typical response times were much longer, hindering wildlife retrieval efforts (Jay Bellinger).

The most intensive search effort in terms of frequency seems to have occurred in Prince William Sound, where all or nearly all shorelines were said to have been searched two to three times per week until June 15 (Kelly Weaverling). Once per week is most often mentioned as a typical search interval. However, this estimate may be an overestimate. Typically, catcher boats were assigned three bays to search, with 2 days of search time required per bay. At a minimum, therefore, the cycle time for a boat to return to its first bay would be 6 to 9 days. If down time is included for supplies, repairs, days off, and weather, the rotation time would more realistically be longer rather than shorter. For example, the catcher boat *Pursuit* went from Cape Chiniak south to Missak Bay and then north again to Hallo Bay in 9 days, a one-way distance of 202 km of shoreline. It is unlikely, though not impossible if a crew were exceptionally determined, that all of the shoreline, rocky as well as sandy, could be searched on foot in that space of time. It is known that the crew spent a considerable amount of time picking up 3,000 birds from the bays in this area, with 800 from Hallo Bay alone in 1 day (Jay Wells). It is, therefore, reasonable to conclude that little of the rocky shoreline was searched. This conclusion is confirmed by Jay Wells.

Inclement weather also inhibited searches. For example, Karen Jettmar stated that along the Kenai coast, "It has been raining for a week throughout Prince William Sound and the Gulf of Alaska. Cleanup efforts have been hampered considerably by stormy weather and rough seas. Today was no exception" (Trip report, April 27, 1989). At Aniakchak, Jerry Bronson stated that on only 2 of 10 days was weather safe enough to patrol remote beaches (Microfilm 003-0998), and he further noted that bears patrolled the beaches after storms, whereas Veco crews were inhibited from landing on beaches until seas subsided. Weather in the Gulf of Alaska undoubtedly interfered with the ability of the bird search and rescue crews to conduct searches.

At Kenai Fjords, actual diaries of catcher boat crews indicate that Two Arm Bay was searched again after an interval of 11 days (Microfilm 005-1058 to 005-1216). These accounts indicate that an estimate of 4 to 6 days would be unrealistically low and that 7 to 11 days is a more reasonable estimate. Sandy beaches at the Barren Islands were searched on a weekly basis by USFWS refuge personnel. Trip reports are available that give the results of weekly beached bird retrievals. Sandy or walkable beaches along the Katmai coast were apparently searched at the same frequency as the Kenai coast, or once per week.

Sandy beaches along much of the rest of the Alaska Peninsula under USFWS administration were searched much less often, from a minimum of once to a maximum of three times during the summer (Donna Dewhurst, Biologist; Ron Hood, Refuge Manager, Becharof and Alaska Peninsula NWRs, King Salmon; Jay Bellinger, Kodiak), except at Puale Bay, where Wildlife Service personnel at a field camp established June 15 searched the shoreline every 2 days.

Eye-witness accounts are unavailable for Kodiak. One can conclude from data on the number of boats active in the Kodiak zone that the search coverage there was perhaps comparable to the Alaska Peninsula. It may, in fact, have been less because of search priorities directed elsewhere (e.g., to NPS-administered coastline) and because of the extensive Kodiak-Afognak coastline to be searched.

All observers noted that rocky shorelines were searched less frequently than sandy beaches. At the Barren Islands, rocky shorelines were not searched; oiled birds were retrieved only from sandy beaches, which compose 13 percent of the coastline. Along the Kenai coast and much of the Alaska Peninsula, including shoreline under both NPS and USFWS administration, rocky shorelines were searched infrequently, once per month or once during the summer, or were not searched at all. In Prince William Sound, because of its sheltered shoreline, accessibility, and larger number of boats, rocky shorelines may have been searched up to two to three times per week (Kelly Weaverling). At Kodiak, data are lacking on search frequency on rocky shoreline, but it was probably comparable to the frequencies along the Kenai and Alaska Peninsula coastlines.

The search effort was much reduced in Prince William Sound by 15 June (Kelly Weaverling; Brian Sharp) and along the Alaska Peninsula by 1 June, after which the Veco emphasis switched to cleanup (Janice Meldrum). The search did continue, as evidenced by the number of catcher boats employed, although by July it was at one-third of former levels and at the end of July it was at one-sixth of the earlier levels (see table 5-11). On 30 August 1989 reports appeared of fresh oiling at Aniakchak National Monument, and of fresh bird kills on 3 September. Autopsies of these birds showed evidence of internal oil (Microfilm 003-0539, 003-0540). Two bags of oiled shearwater carcasses were on the catcher boat *Columbia* at the end of August and the beginning of September 1989 (Microfilm 003-0848). At the Shakun Islets along the Katmai coast, oil and oiled birds were observed on 1 August (Microfilm 003-0848). At Katmai Bay, Chris Martin observed oil and "bird parts everywhere" on 13 August 1989. During surveys to determine whether catcher boats should be decommissioned, Jay Bellinger found oiled bird parts in August along the Alaska Peninsula. Oil, mousse, and sheen were observed by refuge personnel on Becharof NWR beaches in November 1989 (Microfilm 469-0599). Evidently, at least some of the mortalities later in the summer were due to the *Exxon Valdez* oil spill.

The purpose of this discussion has been to quantify the search effort to the extent possible from the data available at this time. We have recognized from the beginning that, without records of the logbooks of the catcher boats, the degree and distribution of search efforts would be difficult to characterize. Our review of the microfilm records indicates that, while examination of the logbooks would be of assistance, we would still have gaps in our understanding of the process. Because no systematic procedures were used for recording data on the allocation of effort relative to the type of beaches, most of this information is probably irretrievable. Of greater concern is the fact that the search methodology was definitely "pseudo-random." That is, searchers were more likely to concentrate on beaches where they believed carcasses were deposited in large numbers, but we have no way to determine the efficiency with which they selected those beaches. Although it is clear at this point that a significant portion of the vast coastline involved was never searched or was searched very sporadically, the quantification of the search effort remains one of the most difficult to study aspects of the incident.

5.3 Effects of Carcass Burial

Observations in Alaska following the oil spill leave little doubt that burial is an important source of carcass loss on beaches, presumably resulting in undercounts of beached birds. Many carcasses were partially buried at the time of their collection. The implication is that others were completely buried and thus not seen at all. The only information at all on this subject comes from beached bird studies done following oil spills or from baseline surveys to find out typical numbers of beached birds along stretches of coast that might later be subject to oil spills. One such study was done on beaches in southern California from 1975 through 1978 to document densities of beachcast birds. It was found that approximately one-third of all carcasses encountered were partially buried (D. B. Lewis, pers. comm.). In another study following an oil spill in central California, marked carcasses were placed on a sand beach and monitored for loss over time. From the first to second day, 28 to 31 percent of carcasses were lost, and by the end of the third day, more than 70 percent were gone. Although some scavenging by crows occurred, the investigators believed carcass burial and reclamation by the sea to be the major contributing factors (Page et al., 1986).

5.3.1 Anecdotal Information

Impressions of workers on the scene can provide additional clues to the magnitude of the problem. Following the *Exxon Valdez* oil spill, a great many observations from workers were recorded and stored on microfilm or in written reports. We have reviewed more than one-third of the total number of microfilm frames (11,300 of 30,000). Anecdotal information is summarized in the following paragraphs. Citations given are Department of the Interior microfilm reel and frame numbers. The impressions of individuals in the National Parks and Wildlife Refuges, obtained from telephone interviews conducted from 11 to 16 January 1991, are also summarized.

(001-0899) Ray Bane of Katmai National Park conducted helicopter surveys on 1 and 2 May 1989 along the Katmai coast and noted that both the oil and the oiled wildlife were "hidden by clean sand" (1 May 1989). Similarly, he found on 2 May 1989 that much of the oil in Hallo Bay was "hidden under newly deposited sand and (it) seemed that roughly one-third fewer dead birds were present than observed on 1 May 1989, perhaps because the birds were being buried by fresh sand and/or were drifting back out to sea."

(001-0906) In Chiniak Bay on 6 May 1989, Jim Boyd, NPS, noted that he "did not see much oil on confirmed oiled beaches, indicating the oil is being covered with sand." In the Kukak Bay area, he noted, "Many dead oiled birds were buried under the cobble substrate" (001-0920; Colleen Matt (Alaska Department of Fish and Game (AF&G)), 6 May 1989). On the beaches, he observed, "Some oiled birds were almost completely covered with relatively clean sand" (001-0921; Kevin Paulus, 3 May 1989). The Refuge Manager at Becharof NWR surveyed Alinchak Bay on 30 April 1989 and found 190 carcasses in a stretch of about 1 mile. He considered this number a minimum estimate "since much sand/gravel (had) been deposited on top of some birds, and often only a small portion of the bird was visible" (469-0549). In Puale Bay, a team from the *Barb M II* "found 55 to 100 oiled birds buried under logs with sand blown over them" (042-0193).

On 3 May, Edgar Bailey at Ushagat on the Barren Islands reported "Rising tides and offshore winds removed all but about 30 of 111 oiled birds . . . on the northeast beach . . . counted 3 days earlier." On 5 May, he noted "new gravel deposited by surf . . ." and on 21 May that "on the north and west facing beaches many bird carcasses were partially covered by sand and gravel because of heavy surf. . . ." From 26 May to 16 June, he observed, "The remains of many old carcasses buried by gravel deposition reappeared with changing tides and wind directions" (notes taken from Bailey, Edgar: Beached bird surveys in the Barren Islands, April 6-June 16, 1989).

Bud Rice, Kenai Fjords National Park, Seward, noted birds being buried by sand and dead birds among boulders at Black Bay on 14 April. His impression was that Veco searched walkable beaches once per week. Walkable beaches were estimated at 10 to 20 percent of Kenai Fjords National Park coast (410 total miles of coastline) (telephone interview).

Jay Bellinger, the Refuge Manager at Kodiak, also found carcasses buried in the sand and believed that, in the interval between the arrival of carcasses on the beach and Veco's arrival (first birds collected on 15 April), some carcasses had been buried. He found that erosion of sand late in the season uncovered carcasses that had been buried earlier.

Jay Wells, who directed the search effort for NPS, focused collection efforts on the southwest corner of bays, where sandy beaches became rocky; these parts of bays seemed to catch the birds in greatest numbers. He estimated the loss of carcasses due to burial at around 10 percent.

5.3.2 Conclusions

Clearly, at least a portion of the carcasses arriving on a beach will be lost through burial unless they are quickly collected. The rate at which this loss occurs certainly varies from beach to beach according to the substrate and exposure to wind and waves. Rates of burial probably also vary at any given site with weather and sea conditions and tide.

Providing that beaches are searched at frequent intervals (every 1 or 2 days), some estimates might be made by tallying the numbers of partially buried carcasses. This tally was not done following the spill, but on some beaches the numbers of partially buried carcasses may be as high as 10 to 30 percent over a several-day period.

5.4 Scavenging Rates of Beachcast Birds

Following the oil spill, many instances of scavenging of beachcast birds were noted by workers on the scene. These observations produced a tremendous body of anecdotal information demonstrating beyond question that scavenging was a common and widespread occurrence and might seriously affect the capability to obtain accurate estimates of carcass numbers. Carcasses often appeared to be removed by scavengers almost as fast as they were deposited on beaches. Some carcasses were scavenged in place, while others were carried away into the woods. Many of those that were recovered from the beach and taken to collection centers consisted only of plastic bags of feathers and bones.

5.4.1 Anecdotal Information

From observations and comments recorded on nearly 30,000 frames in Department of the Interior microfilm archives, a great deal of information is available to characterize the magnitude of scavenging and to identify scavengers and their habits. Sources of the information include boat logs from bird search/rescue boats under contract to Exxon, records of radio communications from boats to field-command headquarters on the deployment and daily activities of boats, field notes of agency personnel, trip reports of surveys of oil-impacted areas, and reports of long-term studies conducted in oil-impacted areas. We examined about 11,300 microfilm frames and conducted follow-up interviews with individuals to whom the microfilm records referred and with agency personnel that directed the beach-search effort. Representative eye-witness accounts were obtained from all sections of affected coastline: Prince William Sound, Kenai coast, Katmai National Park, Becharof NWR, Aniakchak National Monument, Kodiak Island, and other parts of the Alaska Maritime NWR.

All observations are in relatively close agreement as to the overall magnitude of scavenging and its effect on the recovery effort.

Records indicate that several species were active in scavenging. At least nine different species were seen to scavenge on beachcast carcasses, and workers reported scavenging by these species in all sections of the coastline from Prince William Sound to the Alaska Peninsula. Bears and eagles were the most commonly reported scavengers, at least in part due to their conspicuousness and diurnal habits. In some instances, workers used the presence of bears or eagles to locate dead birds hidden between rocks on rocky shorelines (Aniakchak: Jerry Bronson, Biotech). Intertidal foraging by these animals is a common strategy under normal circumstances, and the increased incidence of available bird carcasses as a result of the spill probably resulted in a greater than normal activity of these species on oil-contaminated beaches. It was noted that bears were observed more frequently on oiled beaches immediately after storms that brought new carcasses ashore (Aniakchak: Jerry Bronson). Significant scavengers included both black and brown bears, especially along the Kenai, Katmai, and Kodiak coasts. Brown bears were found at densities of 0.55 per km^2 on the Katmai and Kodiak coasts (Calkins and Lewis, 1990), and black bears were found at average densities of 3.8 per km^2 on the Kenai coast (Calkins, 1990).

Foxes may have been important scavengers, but their involvement in scavenging is still unclear. They were seen to forage in areas under logs where carcasses were lodged (M. Yurick, Katmai National Park), but they were believed to avoid oiled carcasses (D. Payer, Katmai National Park). Wolverines, although less abundant than bears and foxes, are known for their scavenging habits and were reported from Aniakchak beaches (D. Houston, NPS). River otters, which are known to forage actively in the intertidal zone, were seen at several locations including Aniakchak (D. Houston, NPS) and Paguna Arm of Kenai Fjords National Park (Bud Rice, NPS).

Among avian scavengers, Bald Eagles, gulls, and corvids were apparently the most active. Bald Eagles are abundant throughout the region; e.g., in Prince William Sound, the number of eagles was estimated at 5,124 (Schempf, 1990). Numerous reports are found of oiled-bird remains in eagle nests and roosts, e.g., on the Aniakchak coast (J. Bronson, Biotech) and on Green and Knight Islands (E. Snyder-Conn and P. Scannel). Scavenging may have been an important source of food for some eagles, and workers "regularly found scavenged remains of oiled birds at eagle roosts, which were removed, only to find new oiled carcasses on a later visit" (one roost was visited 20 times (J. Bronson, Biotech)). Scavenging by various species of gulls was often observed. The most frequently noted species was the Glaucous-winged Gull, which is common throughout the area. Sowls et al. (1978) report at least 160,000 in the affected area and estimate that the actual total may be twice that amount. Corvids, including Northwestern Crows, Common Ravens, and Black-billed Magpies, were seen to forage predominantly in the intertidal zone throughout the region. Of the intertidal invertebrates, crabs are probably the most efficient and active scavenger, although one of our radio-tagged carcasses was taken and partially consumed by a sea star (see below).

The observations clearly show that not all carcasses were scavenged in place. Many were carried into the adjacent dunes or woods to be consumed and were discovered only accidentally. One of the radio-tagged carcasses that we tracked to the Bay of Isles in Prince William Sound was later recovered by cleanup volunteers. It was in the woods, well back from the beach, surrounded by other bird remains. Bears cached birds as far as 2.5 miles inland for later consumption (Katmai National Park: D. Payer, NPS), and Green and Knight Islands biologists noted that most dead oiled birds found were above the supralittoral zone or in the woods (E. Snyder-Conn and P. Scannel, USFWS). Bears, foxes, and eagles all retrieved carcasses wedged between rocks on rocky coastlines. Oiled carcasses were found repeatedly at eagle nests or roosts (e.g., Aniakchak: Jerry Bronson; Sukoi Bay: Department of the Interior reel-frame 001-1412). In Prince William Sound, at least one and possibly more radio-tagged beached carcasses were tracked to eagle nests. Gulls and eagles also apparently scavenged oiled birds at sea (J. Meldrum, NPS).

Estimates of scavenging rates based solely on incidental field observations vary considerably, but all workers agreed that scavenging represented a significant source of carcass loss, especially on beaches where bears and foxes were present. Scavenging in some areas was apparently so intense that ". . . carcasses of birds may last only a few hours . . ." (Aniakchak: Judy Alderson, NPS). On Green and Knight Islands, almost "all oiled birds collected had been scavenged by gulls or eagles, and frequently only pieces or feather balls remained" (E. Snyder-Conn and P. Scannel, USFWS). Yet the degree of scavenging incidents was quite variable, possibly due to the variation in the length of time that carcasses were present on beaches before searchers arrived. Of 34 carcasses found at Alinchak Bay on one occasion, all were fully scavenged (Ron Hood, USFWS). However, on another date, workers estimated that only 15 percent of the birds had been at least partially scavenged. At Katmai National Park and Preserve, Jay Wells (NPS) estimated that 25 percent of carcasses found had been scavenged, but for other places along the Alaska Peninsula and on Kodiak, morgue workers reported that about 78 percent of the carcasses had been scavenged.

The real question is what proportion of the carcasses deposited on a beach are lost through scavenging. Jay Wells (NPS) at Katmai, estimated that about 10 percent of the total number were carried into the dunes by scavengers, but this proportion would be expected to be much higher in areas where the proportion of carcasses scavenged was higher. Clearly, it is only by a diligent search that these carcasses were discovered at all. The proportion of carcasses removed may be quite variable from location to location. On the Barren Islands, where there are no mammalian scavengers, Edgar Bailey (USFWS) found ". . . no evidence of carcasses being removed from beaches by scavengers."

5.4.2 Quantitative Studies

Although this information clearly shows that scavenging was a significant cause of carcass loss, in this case anecdotal information alone does not provide a quantitative basis for estimating the number of carcasses not enumerated due to scavenging. Ideally, we would wish to know the rate at which carcasses were lost on each day following carcass deposition (expressed as a percentage of the numbers originally present) and the factors affecting that rate. To date, four studies have provided values of carcass loss due to scavenging, over time, in Alaska or in similar coastal environments (some additional work done in Europe is of limited application). Incidental to our radio-tracking work in Prince William Sound, we conducted a study focusing on the fate of freely drifting radio-tagged carcasses that beached at locations that could be safely visited. We also conducted a more structured study using 23 Crested Auklets that were placed above the tide line on beaches of Naked Island and monitored for scavenging. In January of this year, we independently conducted a third study of scavenging along the outer coast of Washington State. A fourth study, recently conducted by A. E. Burger of University of Victoria, collected information on the rate of scavenging along the coast of Vancouver Island, British Columbia.

5.4.2.1 Studies in Prince William Sound

During the course of the radio-tracking study, we released a total of 76 carcasses in Prince William Sound; of these, 41 carcasses ultimately were beachcast. Through search by the boat team, 9 beached carcasses were located, and they were checked every 24 hours until they had been removed through scavenging or refloating. The known history of each carcass after it beached was used to calculate the likelihood that a carcass, once beached, would disappear (due to scavenging) after a given number of days on a particular beach. Carcasses that refloated and were cast up again on another beach were treated as separate trials; this treatment resulted in 14 instances of beaching for the 9 carcasses. In figure 5-16, Time 0 is defined as the first arrival of a given carcass on a given beach regardless of whether that carcass had been previously beached. We found that these carcasses disappeared at a rate of about 50 percent per day, with no carcass lasting more than 4 days on any beach. In two instances, the scavenger had carried away the body but had left the legs and radio tags behind on the beach. It is likely that the scavengers would have removed the entire carcass if not for the presence of the radio tag. Two other carcasses had been entirely removed from the beach and were believed to have been taken by mammalian scavengers (a black bear was seen only

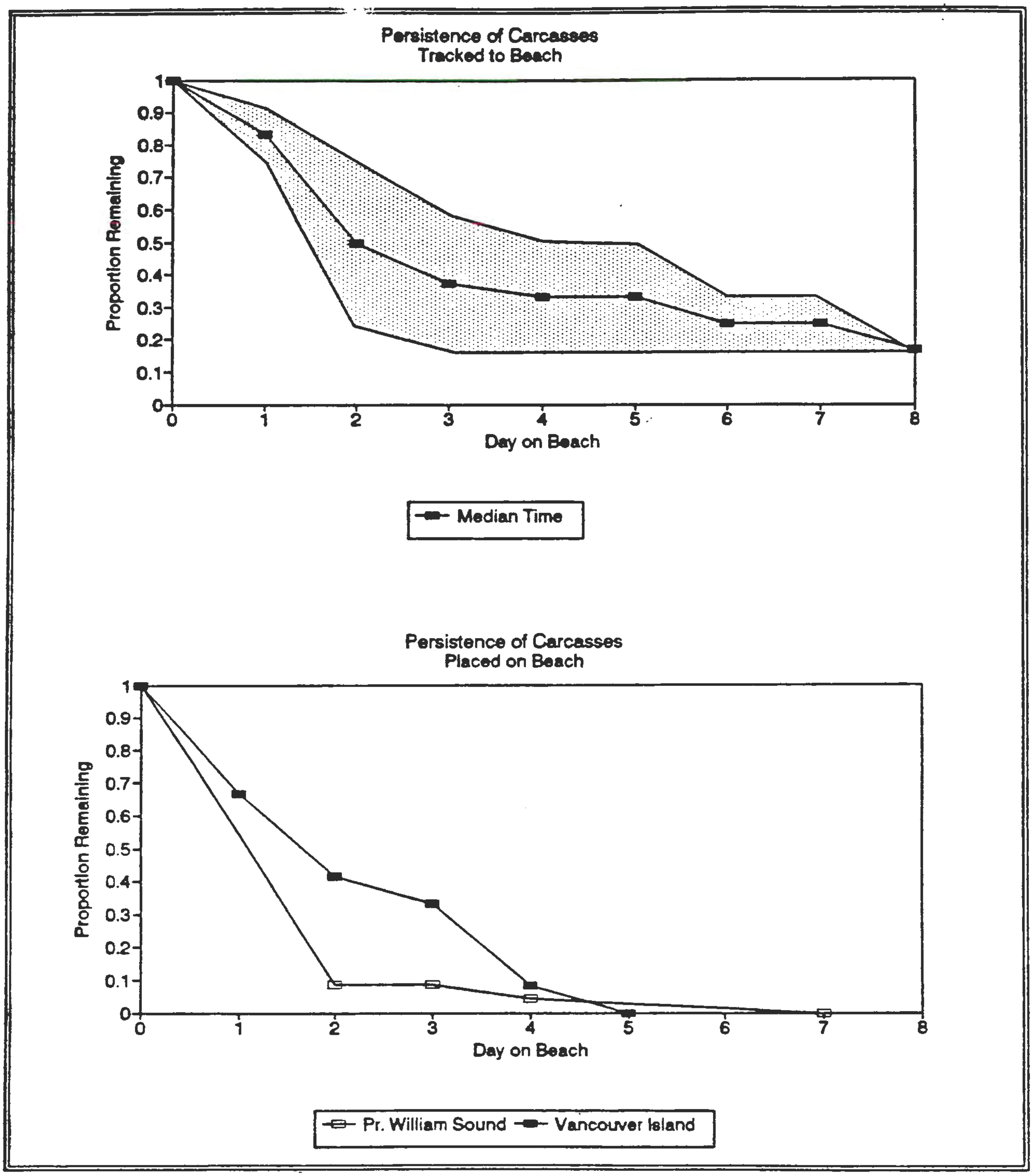


FIGURE 5-16. The persistence of beached carcasses in the Naked Island complex and the northern end of the Knight Island complex in Prince William Sound during late May and early June 1990. The carcasses were considered to be missing either after they had been removed from the beachface or when only small quantities of feathers and bones remained. The stipled area in the upper figure reflects uncertainty in the exact time of removal.

200 meters (m) from the remains). These carcasses would not typically have been recovered by workers searching the beaches. Most other carcasses were taken by birds that carried a carcass back from the beach where the carcass was opened, and the pectoralis and organs were eaten. In one case, a carcass was claimed by a sea star (Solaster). Although unusually calm conditions may have allowed the sea star time to grasp the carcass, the scavenging abilities of these and other invertebrates (particularly crabs) should not be underestimated.

Another experiment was conducted using 23 Crested Auklets that were unsuitable for the drift studies. In this work, conducted in June of 1990 at six sites on the Naked Island complex, groups of carcasses were placed on two different shoreline substrates: steep, rocky intertidal beach and gradually sloping cobble beach. One carcass on each beach was radio tagged to aid the observers in determining if carcasses had rewashed. Within the first 2 days, 21 of the 23 carcasses had been carried off by scavengers (figure 5-17).

5.4.2.2 Studies in Washington State and Vancouver Island, Canada

In January of 1991, we conducted an independent study of scavenging rates at Kayostla and Cedar Creek beaches on the outer coast of the Olympic Peninsula in Washington. For this study, we used carcasses of Common Murres that had been recovered after the *Nestucca* oil spill; all were cleaned and free of oil. Three lines of 27 carcasses each were used (A, B, and C). Lines A and B were placed on a gently sloping sand beach protected by offshore rocks. At higher elevations, the beach had accumulated large numbers of drift logs extending to the edge of the forest. Four additional carcasses were placed on this beach between the higher high-tide and lower high-tide lines. Line C was placed on an adjacent steeply sloping cobble beach with two or three berms in which drift logs were buried. This beach had little protection from reefs and was probably subject to greater wave action. Carcasses were provided with a leg band and positioned over a cork float. If a carcass were removed by scavenging, only the float would remain. If the carcass were rewashed by the surf, both the carcass and the float would be missing. Over a 5-day period, each line was examined morning and afternoon. Carcasses were scored as present, removed by scavenging,

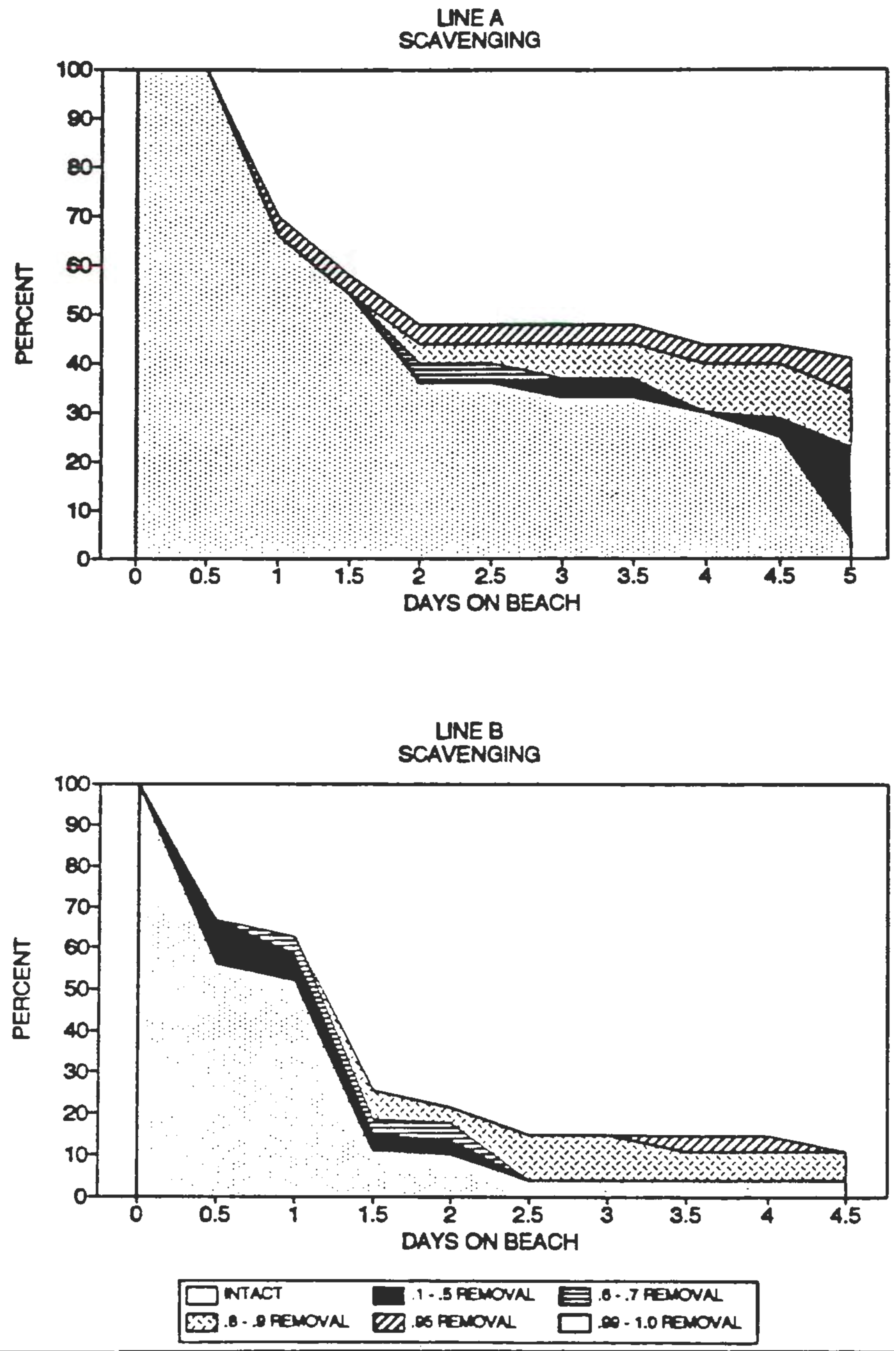


FIGURE 5-17. Results of a scavenging study carried out in Olympic National Park in January 1991. Lines A, B, and C represent three groups of 27 bird carcasses placed on three different beaches. The width of each stipled band represents the percentage of carcasses in each state as time progressed. A removal level of 0.99 indicates that only feathers or a fraction of a leg remained. A removal level of 1.0 indicates that no trace of the carcass remained on the beach.

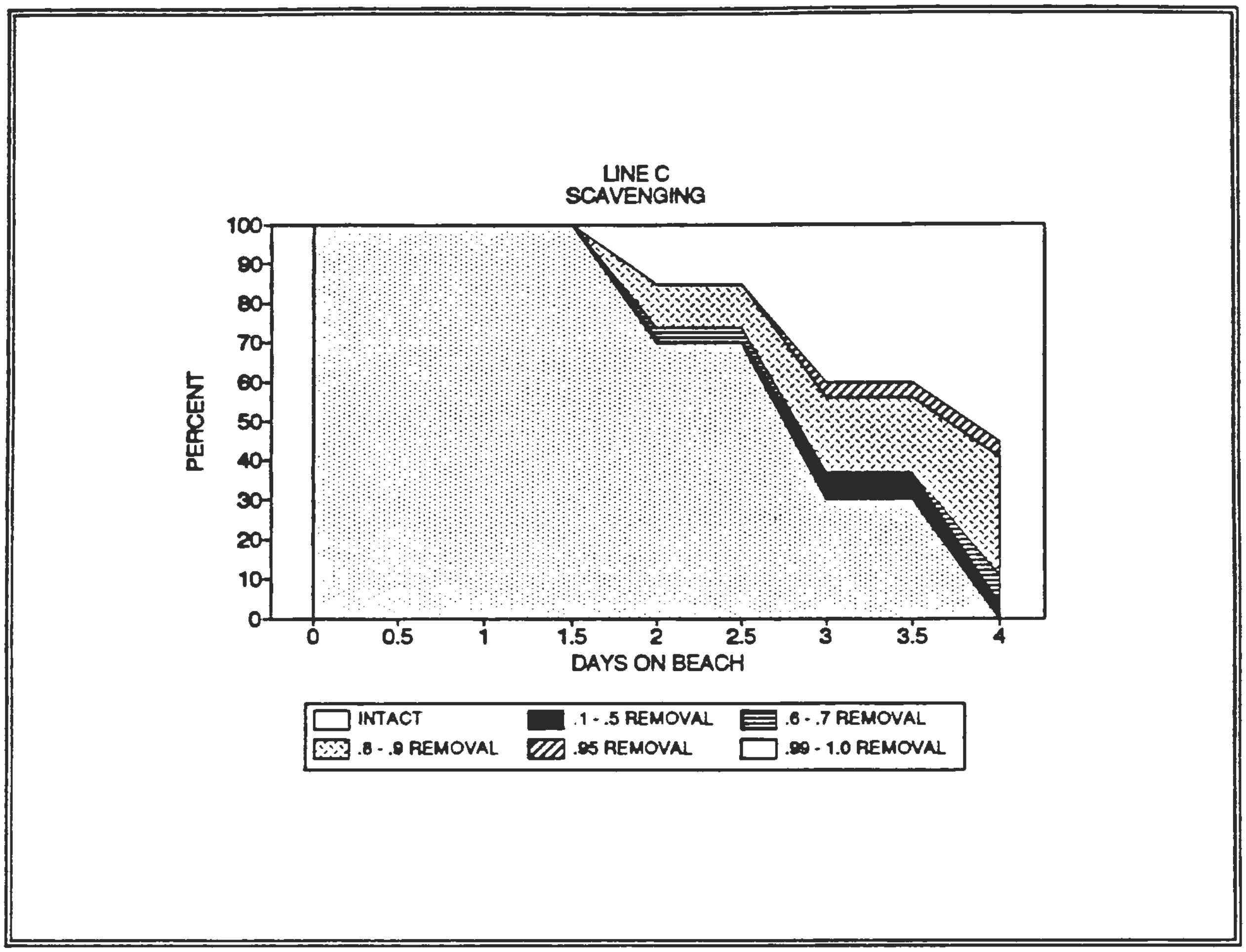


FIGURE 5-17. (cont'd.)

scavenged in place (with the percentage of the carcass that was eaten), or removed due to rewashing.

Carcasses persisted on the beach face before being scavenged for a mean of 2.55, 1.08, and 3.00 days (Standard Deviation (S.D.) = 1.66, 0.65, 0.80) for lines A, B, and C, respectively. The distribution of first scavenging events over time varied significantly from line to line (G test, 0.05,8, = 62.63). Line B was scavenged immediately, line A was untouched for 0.5 days, and line C was untouched for 1.5 days. After scavenging began, it proceeded rapidly with 50 percent of all carcasses removed after 1.5 days, 1.2 days, and 3.7 days for lines A, B, and C, respectively. Some carcasses were scavenged as many as four or five times through the 5-day monitoring period, but the calculation of means showed only slightly more than one scavenging event per carcass (1.26, 1.48, and 1.11 for the three lines). That is, scavenging was typically a discrete event, with the carcass being completely removed or eaten. All but two of the carcasses were scavenged to some degree over the course of the study. Figure 5-17 shows the portion of the total number (expressed as a percentage) that remained on any day. For line A on the sandy beach, more than 60 percent of the carcasses had been removed or almost completely consumed within 2 days and, after 5 days, about 77 percent had been removed or almost completely consumed. For line B on the same beach, the degree of scavenging was even more dramatic. Here, 77 percent were removed or almost completely eaten after only 1.5 days, and more than 95 percent were eaten or gone after 5 days. For line C on the steep cobbled beach, no scavenging occurred in the first 1.5 days but, once the carcasses were discovered, 95 percent were removed or eaten in place within 4 days. From sightings or tracks, we believe the predominant avian scavengers were eagles, ospreys, gulls, and crows and the predominant mammalian scavengers were raccoons (tracks only), river otters, and bears (tracks only). Of the four carcasses placed between the higher high-tide and lower high-tide lines, all were scavenged by gulls within the first 7 hours. Although these carcasses were not completely consumed, they were all dragged below the high-tide line, where the remains were carried away by the surf. Gulls did not seem to play any role whatsoever in scavenging carcasses at higher locations on the beach than where drift logs accumulated.

Between 30 December 1990 and 4 January 1991, A. E. Burger conducted a similar experiment at Pachena Beach on Vancouver Island, British Columbia. In this study, 12 seabird carcasses from a local oil spill were placed along the high-tide line and monitored daily. After 1 day, four had been taken (33 percent). After 3 days, eight had been taken (67 percent), and three of the remaining carcasses had been partially eaten. All carcasses were missing after 5 days.

5.4.3 Conclusions

Scavenging is clearly related to the amount of time that a carcass remains on a beach; the longer it remains, the more its likelihood of being scavenged increases. Anecdotal observations and the results of the foregoing studies indicate that scavenging removes many bird carcasses from beaches before they can be recovered. Although the sample sizes in some cases are not large, the results of all studies are similar in their findings. The time course of scavenging apparently is about the same along many wild coasts, with 50 percent of beachcast carcasses lost within 1 or 2 days and most of the remainder gone after 4 or 5 days. This rate of disappearance may actually be a low estimate because none of the areas where scavenging was studied was occupied by brown bears. This holds great consequence for estimates of total seabird mortality based on the numbers counted on shore. Unless beach searches are conducted at very frequent intervals, only a small fraction of the total number of drifting carcasses reaching a beach will ever be counted.

6.0 MODEL COMPUTATIONS

Using the records of bird carcasses logged in at the various bird processing centers as a base, the model projects these numbers back through the processes that affect the recovery of seabird carcasses. These processes include loss from the beachface due to scavenging before the beach is searched, failure to search certain beaches at all, and sinking before making landfall. In the following sections, we discuss the method for determining which part of the morgue data base to use in the analysis, the computation of scavenging loss, the estimation of the number of carcasses unrecorded due to lack of search effort, and the computation of loss at sea.

6.1 Interpretation of the Morgue Data Base

Not all collected birds were necessarily victims of the spill. Because the morgue data base is the starting point for all model calculations, it was important that the records to be included be determined very carefully. Piatt et al. (1990) used 1 August as a general cutoff date in making their estimate of total bird mortality, based on their general assessment of species composition, degree of oiling, and other potential sources of mortality. In determining which morgue records to include as our model base, we have relied heavily on our reexamination of the sample of birds in the Kodiak morgue vans. On the basis of our analysis of this sample, we have selected a subset of the morgue data for use in the model projections. We have also determined that it is appropriate to treat murres separately from other taxa.

As is common in North Pacific oil spill incidents, murres (Common and Thick-billed) account for a large proportion of bird mortality in the *Exxon Valdez* spill. The 19,799 carcasses identified as murres in the morgue data base constitute 56.6 percent of the birds (see table 6-1). These deep-diving seabirds have behavioral characteristics, such as spending much of their time resting on the surface of the water and diving when startled or distressed,

TABLE 6-1. Summary of numbers and proportions of carcasses coded Common Murre, Thick-billed Murre, or Unidentified Murre and all other codings in the morgue data base.

MORGUE	MURRES NUMBER	(%)	NON-MURRES NUMBER	(%)	TOTAL BIRDS NUMBER	(%)
Valdez	436	(12.98%)	2,922	(87.02%)	3,358	(100.0%)
Seward	1,442	(41.16%)	2,061	(58.84%)	3,503	(100.0%)
Homer	3,361	(61.33%)	2,119	(38.67%)	5,480	(100.0%)
Kodiak	14,560	(64.32%)	8,076	(35.68%)	22,636	(100.0%)
Total	19,799	(56.61%)	15,178	(43.39%)	34,977	(100.0%)

which make them extremely vulnerable to the effects of floating oil. In addition, they readily absorb large amounts of oil into their plumage, and even small amounts can be fatal, especially in cold waters. A reexamination of a sample of carcasses in the Kodiak morgue (see section 3.0) suggests that the number of murres in the morgue may in fact be higher than morgue records indicate. This results in large part from the identification of many murres as "alcids" or "birds" in the morgue data base. The reexamination of carcasses also indicates that a large proportion of murre carcasses recorded after 1 August were oiled. For these reasons we have treated murres as a separate category for modeling purposes. We believe the base numbers to be conservative, and have not applied a date cutoff to murre species records.

Other taxa in the morgue data base include many species of puffins, other alcids, gulls, tubenoses, loons, grebes, cormorants, ducks, shorebirds, passerines, and other birds. Although there is some variation in temporal oiling patterns among the various groups (see section 3.0), oiling rates generally decline to markedly less than 50 percent after 30 June. Although some oiled birds are recorded after that date, other sources of mortality are likely for many specimens. To avoid using late season natural dieoffs as a base for calculations of oil-induced mortality, we have applied a cutoff date of 1 July to all non-murres. We have allocated a portion of carcasses coded as Unidentified Alcid or Unidentified Bird to the murre category, consistent with the results of our reexamination of carcasses.

It is known that certain carcasses were never delivered to the morgues and are thus not included in the morgue data base. These include carcasses inadvertently discarded with other oily debris and carcasses burned because of safety concerns and other circumstances. We have added to our carcass counts those carcasses known to be in these categories: 631 burned at Gore Point, 500 burned at Afognak, 100 burned at Hallo Bay, and 2,000 discarded in oily waste in the Kodiak sector. (See table 6-2.)

TABLE 6-2. A summary of the numbers and proportions of murres and non-murres used as a best estimate base for model calculations. Mortality of non-murres from 1 July is presumed to result from natural causes. Murres include carcasses coded as Common Murre, Thick-billed Murre, or Unidentified Murre, as well as an allocated proportion of carcasses coded as Unidentified Alcid or Unidentified Bird. Non-murres include all other taxa.

	Murres		Non-murres		Total Birds	
Morgue	Number	(%)	Number	(%)	Number	(%)
Valdez	437	(13.07%)	2,907	(86.93%)	3,344	(100.0%)
Seward	1,869	(54.75%)	1,545	(45.25%)	3,414	(100.0%)
Homer	1,546	(67.08%)	1,740	(32.92%)	5,286	(100.0%)
Kodiak	15,752	(88.47%)	2,052	(11.53%)	17,804	(100.0%)
Total	21,604	(72.38%)	8,244	(27.62%)	29,848	(100.0%)

6.2 Scavenging Model

The process of scavenging on beachcast birds leads not only to the reduction of carcasses to piles of bones and feathers that are still recognizable as scavenged carcasses, but also often results in the removal of the entire carcass or in the reduction of the carcass to minuscule, unrecognizable fragments. In general, scavenging on a collection of beachcast carcasses proceeds until the remaining fragments are of no interest to scavengers. These fragments probably persist until physical factors such as storms or exceptionally high tides clean the beaches of the debris. When the proportion of carcasses remaining (either whole or partially scavenged) on the beach is plotted against time, the process is seen to be approximately exponential: Carcasses disappear rapidly at first, and more slowly as time goes on.

Studies from Prince William Sound, Vancouver Island, and the Olympic Peninsula consistently show that enumeration of entirely or partially scavenged carcasses substantially underestimates the number of carcasses originally on the beach. The time course of the process was found to be very rapid, with one-half or more of the carcasses disappearing within one to two days. By comparison, we found that the time elapsing between visits to the same beach by bird recovery personnel was typically more then a week everywhere except Prince William Sound and Cook Inlet. Because carcasses could come ashore at any time within that interval, it is clear that most of them had been on the beach long enough for a significant decrease in "countable" carcasses to have taken place. That significant scavenging had occurred by the time carcasses were recovered is shown by the Kodiak morgue data base, which includes counts of the number of carcasses scavenged as well as the number of carcasses recovered. In this data base, 78 percent of the carcasses were recorded as having been partially scavenged. This was corroborated by our examination of birds from the Kodiak freezer vans, where many carcasses were represented only as wings, legs, feathers, or sterna. In this part of the model, we use experimentally derived estimates of the loss rate due to beach scavenging to correct the number of carcasses remaining on the beaches to the number of carcasses actually deposited.

Our basic information is an empirical function describing the proportion of carcasses remaining on a beach as a function of the number of days on the beach. Let Cb_i represent the number of carcasses arriving on a given beach on day i, m be the number of days between searches of that beach, Cr be the number of carcasses recovered on day m, and Ss_j be the likelihood that a carcass will survive j days on the beach. Then the number of carcasses recovered on day m will be:

$$(1) \quad Cr = \sum_{i=1}^{m} (Cb_i \, Ss_{(m-i)})$$

In practice, it is not possible to tell how many carcasses arrived on a given day on a given beach because beaches were visited only sporadically. Depending on wind and tide conditions, the carcasses might have been deposited in a single clump at any time during the m days between searches, or they might have been deposited in about equal numbers each day. If we assume that the deposition rate is constant, however, the expected value of Cr, when computed over many beaches, remains the same as if the number arriving on a given day were a random variable (see appendix D).

Let Cb* be the sum of the Cb_i (in other words all carcasses coming ashore between 1 and m), and assume that the rate of deposition is constant. Then:

$$(2) \quad Cr = \sum_{i=1}^{m} (Cb^* / m) \, Ss_{(m-i)}$$

$$(3) \quad Cr = (Cb^* / m) \sum_{i=1}^{m} (Ss_{(m-i)})$$

$$(4) \quad Cb^* = m \, Cr / \sum_{i=1}^{m} (Ss_{(m-i)})$$

This holds as long as the number of carcasses deposited on day i, Cb_i, is independent of i and therefore of Ss_i, in which case the expectation of Cb* is equal to the expectation of the sum of the Cb_i.

Two observations suggest that non-independence between Ss_i and Cb_i may have sometimes occurred. (1) Because carcasses appeared to be beachcast following storm events, a weather-induced lag tended to occur in some areas between deposition of carcasses and arrival of the search crews. This lag, however, did not seem to apply at least to highly visible scavengers such as bears and eagles, which were frequently observed to be present immediately following storms. Also, (2) the speed with which scavengers, bears in particular, keyed in on freshly deposited carcasses tended to delay the arrival of recovery personnel who were under instructions for safety reasons to avoid beaches with bears. Both of these factors would cause the time of recovery to lag behind the time of deposition more than if the two events were independent. This lag would provide more time for the removal of carcasses by scavengers than would be the case if the number of carcasses deposited on day i were independent of i, and may result in an underestimate of Cb*.

When the above approach is used, the necessary pieces of information for the estimation of carcass loss due to scavenging are the length of time between visits to a given beach and the loss rate function Ss_j. Estimates of the length of time between visits ideally should be made from logbooks of the boats engaged in the recovery effort. Because these have not yet become available, we used the estimates based on interviews with Government personnel familiar with portions of shoreline over which their agencies had jurisdiction (see section 5.2). For the scavenging rate function, we use data from three sites—Prince William Sound, Vancouver Island, and the Olympic Peninsula. These data are the best available at this time, and all show a rapid dropoff in the number of recoverable carcasses on the beachface. The form of this rate function, however, undoubtedly varies with the beachtype and with the mix of scavengers. In particular, none of the sites for which we have data includes Brown Bears among the suite of predators. It is possible that the coastline adjacent to the Gulf of Alaska supports a higher density of scavengers than the sites that have been studied.

Two additional factors that could affect the rate at which scavengers removed carcasses are the effect of oiling on the palatability of the carcasses, and possible satiation of the local scavenger population by huge numbers of carcasses being deposited over a short period of time. In terms of palatability, very little anecdotal evidence was found to suggest any hesitation on the part of scavengers to consume flesh from oiled or heavily decomposed carcasses, although one observer suggested that foxes appeared to be inhibited by the presence of oil. Satiation of the scavenger community may have occurred in some instances, but we doubt that this was a frequent occurrence given the ubiquity of scavengers and the enormous length of coastline over which the carcasses were deposited. Bird recovery personnel typically noted densities of about one carcass every 10 m or more, which are the same densities at which the studies on the Olympic Peninsula and Vancouver Island were carried out. On the other hand, at Hallo Bay personnel recorded 800 birds at densities of several per meter. Such a concentration of birds, however, would have extended only about 400 m and would have been accessible to many scavengers. In fact, it was unusual for recovery personnel to turn in groups of more than 50 birds from a given location at any one time. About 93 percent of the groups of carcasses logged into the morgues consisted of 50 or fewer carcasses.

We looked for evidence of a satiation effect by plotting the number of scavenged carcasses turned in from a given location on a single day against the total number of birds turned in from that location on that day (figure 6-1). One would expect that a strong satiation effect would result in a proportional decrease in the number of scavenged carcasses as the number of birds recovered from a given location increases. This relationship is not evident even when very large numbers of birds were collected at one time.

6.3 Search Effort Model

Beaches that were never searched represent a potentially significant source of the undercount of carcasses. Based on the digital ESI data, the total length of coastline where carcasses might have come ashore encompasses about 10,000 - 16,000 km of some of the most rugged shoreline in North America. A significant portion of this shoreline consists of substrates that are difficult or impossible to search, but where carcasses would nonetheless have been deposited.

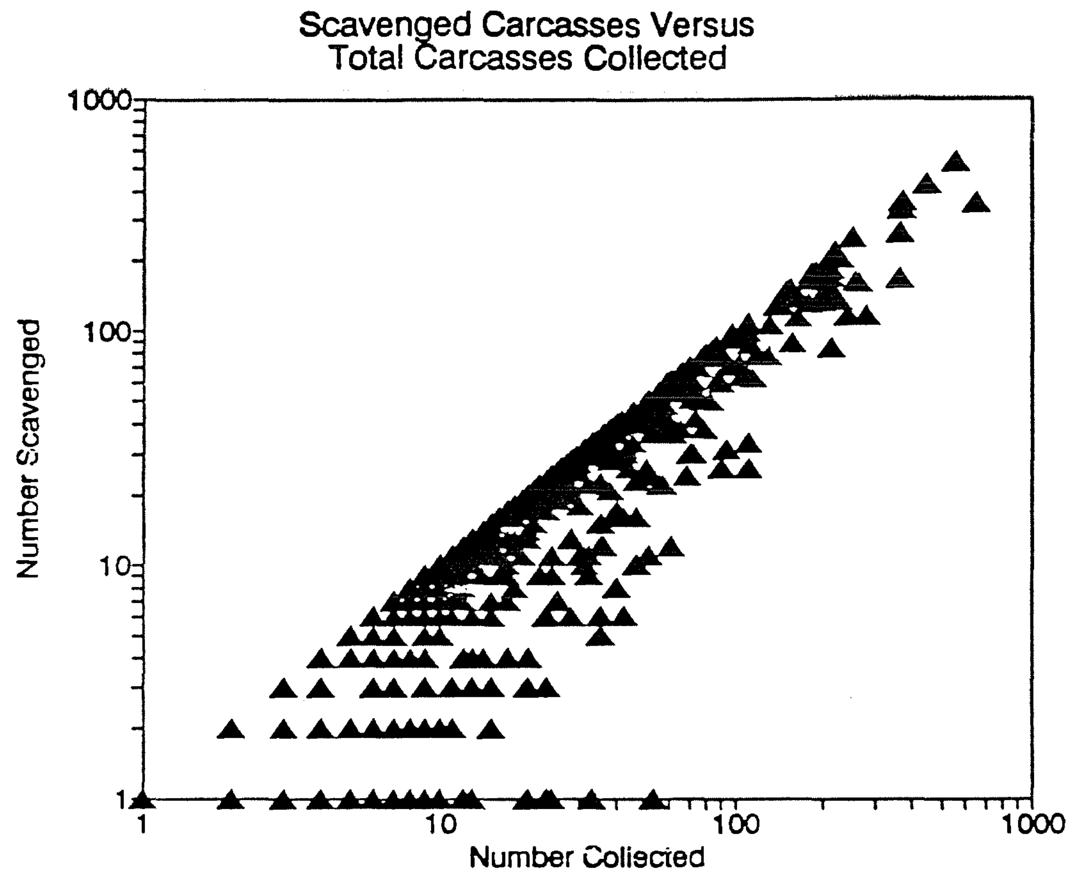


Figure 6-1. The number of scavenged carcasses collected from a given location and processed on a given day plotted as a function of the total number of carcasses from that place and processing date. The data points cluster along the 1:1 line because more carcasses could not be scavenged than were in the group. The relationship shows no indication that the proportion of scavenged carcasses declined when very large groups of carcasses were recovered at the same time and place.

Determining how much of this coastline actually was searched is difficult because consistent records apparently were not kept regarding the extent and nature of the search effort. Searchers went where they believed carcasses to have been deposited, but to our knowledge there was no attempt to direct their efforts in a systematic way. The pattern of the effort appears to have sometimes been relatively predictable, with boats sequentially working their way down the coastline. At other times the boats appeared to have returned frequently to areas where they had once found large quantities of carcasses. The lack of consistent record keeping and the lack of a sampling methodology makes the analysis of the search effort difficult. Some important information, notably which general areas were searched and how often, can probably be recovered from the logbooks of the vessels engaged in the search if they become available in the future. We have inspected some of these, which are included in the records of the case. If these logs are typical, this information can be reacquired. Other kinds of information, such as what type of beaches were searched (e.g., sand, large cobble, rocky intertidal, etc.) and the actual length of beach searched, may be permanently lost in many cases except for the recollections of the people involved in the search effort.

In spite of these difficulties, it is not appropriate to ignore the effect of unsearched beaches entirely, and to assume that every mile of the Gulf of Alaska where birds were deposited was checked by bird recovery personnel. At this point, we can only use existing shoreline typing information and interviews to make a rough estimate of the undercount resulting from unsearched areas. This estimate can probably be refined using information contained in the vessel logs and some additional information on the walkability of certain types of shoreline.

Shorelines vary greatly in terms of their walkability and the effectiveness of searching. Sand and small gravel beaches are generally easy to walk on, and carcasses are easy to see unless they are partially buried in the sand, covered in the wrack line, or covered with mousse. In contrast, large cobble or boulder beaches, consisting of rounded stones 6 inches in diameter or larger, can be traversed only slowly and with difficulty. On this substrate, carcasses can be very difficult to detect because they often resemble the surrounding rocks in size and shape, especially if both are coated with oil. Similarly, wave cut platforms, expanses of bedrock sometimes more than a kilometer wide and containing both boulders and tidepools, can be very difficult to cross. Carcasses may be partially submerged in tidepools or in crevices under rocks and not be detectable except from a short distance. Other types of shorelines, notably steep rocky walls, are known to reflect oil, and we assume that bird carcasses would for the most part be reflected. It should be noted, however, that there are observations of moussed carcasses stuck onto rock walls and of carcasses lodged in cracks in the rocks.

We estimate the proportion of coastline which was searched by looking at the 15′ latitude/longitude cell where the birds were recovered. We assume that carcasses were deposited with equal frequency on any non-reflective substrate within that cell proportional to the frequency with which that substrate occurred within that cell. We use ESI shoreline typing data to divide the cell into searchable, unsearchable, and reflective portions. Exposed and sheltered rocky shorelines, and unclassified (mostly offshore rocks) are assumed to be reflective. Sand, mixed sand, and gravel beaches and exposed (sandy) tidal flats are assumed to be fully searchable. Gravel beaches, exposed wavecut platforms, and marsh are assumed to be partially searchable, and sheltered tidal flats (mud) are assumed to be unsearchable. We assume that all the carcasses on depositable but unsearchable beaches were missed, and that a fraction of the carcasses on searchable beaches were missed. Estimates of the proportion of the carcasses on searchable beaches that were missed were made based on conversations with NPS and USFWS personnel familiar with the various areas.

The following method is used to estimate the number of birds not enumerated due to a less than complete search effort. Let k be one of 12 ESI shoreline classifications. Let L_k be the length of coastline of type k within a 15′ cell, R_k be a variable that assumes the values of 0 or 1 depending on whether the substrate is reflective or depositable, Pw_k be the proportion of substrate k that was accessible, and Ps_k be the proportion of accessible substrate k that actually was searched. Then the proportion of the depositable fraction of the entire cell that was searched, P*, is

$$(1) \qquad P^* = \sum_{k=1}^{12} (R_k \, Pw_k \, Ps_k \, L_k) \Big/ \sum_{k=1}^{12} (R_k \, L_k)$$

If Cb* is the number of carcasses deposited on searchable beaches between searches, those carcasses represent a subset of the larger number of carcasses deposited on all beaches, Cs. We assume that some of these carcasses were not found because they beached in areas that were never searched, and that within a 15′ cell the likelihood of beaching is independent of the substrate. Then:

(2) $Cb^* = P^* Cs$

(3) $Cs = Cb^* / P^*$

The assumption that substrate and likelihood of beaching are independent needs to be tested. If the assumption does not hold, then the method used to compute Cs must be modified. We will test this assumption by analyzing the overlap between substrates and oiling when the digital version of the oiling data becomes available from the State of Alaska.

6.4 At-Sea Loss Model

The bodies of seabirds that die at sea may float for days or weeks without reaching shore. Some of these bodies will become waterlogged and sink or be scavenged enroute to shore, and thus never be enumerated as beached birds. Carcass drift experiments in the Gulf of Alaska show that the rate at which this attrition takes place changes with the age of the bodies. Relatively few carcasses sink until they have been floating for a week to two weeks, after which time they begin to disappear rapidly, and by the end of the third week few remain afloat. Under these circumstances, it is clear that if seabirds die near the coast, with wind and sea conditions conducive to their being pushed onto shore, most of the bodies would be cast up on the beach. On the other hand, if the birds are killed far offshore or if wind and current conditions are not conducive to the bodies being beached, few of them may ever come ashore.

In the *Exxon Valdez* incident, oil continued to move southward along the Kenai and Alaska Peninsulas and to come ashore in new areas at least through the middle of May. Because oil slicks and bird carcasses tend to drift together, we can conclude that a bird killed back at the beginning of April, when oil was flowing from Prince William Sound out into the Gulf of Alaska, might not have come ashore for as much as 6 weeks or longer — a time span that would result in the loss of a large proportion of the carcasses before they ever made landfall. Obviously, there was the potential for large numbers of birds to be lost at sea without ever coming ashore, but how many were lost depends on the movement pattern of the slick relative to the spatial distribution of the seabird population.

To estimate the number of birds that were lost at sea, we work backwards from the bird carcasses recovered on a particular beach and try to determine where they succumbed to the effects of oiling. To do this, we use the distribution of the birds at sea and the output of the NOAA HAZMAT OSSM. This model maps the spill as a cluster of independently moving points (a Lagrangian element), each representing a piece of the entire slick. These points are each subjected to the interacting effects of winds and currents and form a composite image of the extent and position of the oil slick through time. Focusing on a single element of oil coming ashore on a given beach, we work backwards along the path of that element to determine where along its path the birds that were deposited on that beach would have contacted the slick. Suppose, for example, that 10 murre carcasses were determined to have come ashore on a stretch of beach on 30 April. Looking at the trajectory of the Lagrangian elements arriving on that beach on that day, we determine that they passed through two similar concentrations of murres, one 6 days and one 11 days prior to beaching. Assuming that a similar amount of oil passing through similarly dense concentrations of murres would result in roughly equal levels of mortality, then equal numbers of birds were killed 6 and 11 days before beaching. Based on the known rates of carcass loss at sea, about 45% of the birds killed 11 days earlier would still be afloat, and about 95% of the birds killed 6 days earlier would still be afloat. The 10 murres beached on 30 April would thus represent (45% + 95%) / 2, or 70% of the total mortality caused by the oil arriving on that day. This means that those 10 murres actually represent 10 / 0.70 = 14.3 murres — between 4 and 5 of the carcasses actually having been lost enroute to shore. Obviously, actual implementation of the model is more complex because multiple elements of oil are involved and because bird distributions usually consist of continuously varying densities rather than a few dense concentrations.

The model is constructed as follows. Let B_i be the density of birds at the position of a Lagrangian element on day i. Let r be a proportionality constant relating the density of birds to the number of birds D_i, killed by the oil, represented by the Lagrangian element on day i. Then:

$$D_i = r\,B_i \tag{1}$$

If a Lagrangian element is released on day 1 and beaches on day n, the total mortality, T, attributed to that element is:

$$T = r \sum_{i=1}^{n} B_i \tag{2}$$

If some of the carcasses have been lost at sea, the number of carcasses beached will be less than T. To compute how many carcasses were lost, let S_j be the probability that the carcass of a bird killed j days ago will still be afloat, and let Cb_n be the number of carcasses beached on day n. Then:

$$Cb_n = \sum_{i=1}^{n} r\,B_i\,S_{(n-i)} \tag{3}$$

The essence of the damage assessment problem relating to beachcast birds is to compute T given Cb, B, S, and n. The ratio of recovered carcasses, Cb*, to total mortality, T, can be represented as:

$$\frac{Cb_n}{T} = \frac{r \sum_{i=1}^{n} (B_i\,S_{(n-i)})}{r \sum_{i=1}^{n} B_i} \tag{4}$$

$$(5) \qquad T = Cb_n \frac{\sum_{i=1}^{n} B_i}{\sum_{i=1}^{n} (B_i \, S_{(n-i)})}$$

If multiple Lagrangian elements arrive in the same beaching area on the same day, the $\sum_{i=1}^{n} B_i$ and the $\sum_{i=1}^{n} B_i \, S_{(n-1)}$ are computed over all Lagrangian elements. This is equivalent to the assumption that r is invariant over the Lagrangian elements — i.e., that each element represents the same quantity of oil.

This expresses the total kill represented by a group of carcasses arriving on a given beach on a given day in terms of at least potentially knowable parameters: (1) the number of carcasses recovered, (2) the probability that a carcass of a given age will still be floating, (3) the trajectory followed by the oil between the point of release and the beach, and (4) the density of birds intersected by the oil along its path.

One difficulty encountered in applying this model to the Valdez incident is that the Lagrangian element model developed by NOAA HAZMAT terminates at the end of April as the oil was moving down Shelikof Strait and the eastern side of Kodiak. Based on their overflights and observations, HAZMAT personnel indicated that oil had remained in these areas for several months, beaching periodically with shifts in the winds. Recoveries of bird carcasses show a similar pattern. If we assume birds are evenly distributed in the Shelikof Straits area and in the area east of Kodiak (but at different densities in the two general areas), and that birds in the Gulf of Alaska north of Kodiak are also evenly distributed with a density equal to the mean density of this area, it is possible to use the model described above for estimating carcass loss at sea. We assume that each of the Lagrangian elements beached in these areas intersected birds during the month of April based on the average of all elements remaining in the Gulf of Alaska or passing either to the east or west of Kodiak Island, or remaining north of Kodiak Island. After the end of April, elements are assumed to have remained in these general areas encountering constant densities of birds until they were beached.

Development of equations 6.4 (1) through 6.4 (5) requires two assumptions that may or may not always be met. First, it is assumed that the proportionality between the density of birds and the mortality resulting from a given quantity of oil is constant. Although this assumption is probably met over relatively short time spans, over periods of weeks or months it is likely that the lethality per unit volume diminishes as the oil decreases in volume and viscosity and progressively weathers. Violation of this assumption would mean that in fact, the birds recovered on a given beach would be older than the model predicted. Suppose, for example, that a patch of oil passing through a region of constant density of birds was lethal for the first 10 days, but had no effect after the tenth day. If we assumed that the oil was equally lethal from the first through the twentieth days, we would estimate that half of the birds had been at sea 1-10 days, and half for 11-20 days. Because the hypothetical oil patch had only killed birds for the first 10 days, however, all the birds would actually be 11-20 days old, and none would be 1-10 days old. Because the proportion of carcasses lost at sea increases with the length of time at sea, we would underestimate the actual loss of carcasses as a result of not taking into account the declining lethality of the oil.

A second assumption that is likely to be violated in a very large-scale spill such as the *Exxon Valdez* is that the distribution of birds is static and does not change with the passage of the slick. Given the numbers of birds killed by the slick, this assumption was probably violated. Systematic pre- and post-spill offshore censuses are not available to define the changes in distribution in such a way that they could be modeled as a time varying function. As an alternative, we examined the effect, of assuming an even distribution of murres throughout the area affected by the spill rather than the characteristically patchy distribution indicated by the OCSEAP data base, and of assuming that the density of murres in the

Shelikof Straits area was constant and equal to the densities recorded by Piatt et al. (1989) and that the densities east of Kodiak were a constant density based on the OCSEAP data base. The effect of using an even distributional model rather than a patchy one does not result in a clear directional bias in the final estimate of mortality. If high-density patches are placed such that they occur closer to landfall in terms of the trajectory of the oil, then the use of an even distributional model will overestimate mortality because the birds recovered on the beach would actually have been killed shortly before the oil came ashore. On the other hand, if concentrations of birds tended to occur in areas affected by the oil early on, then most of the beached carcasses would actually be older than would be estimated using the even distributional model. In actuality, the patchiness of the observed distribution for murres based on the OCSEAP data base does not show a strong bias in either direction. Comparing estimates of the number of murres lost at sea based on an even distributional model and a distributional model generated using OCSEAP data for April and May show that the OCSEAP based model is slightly conservative, resulting in an estimate of loss at sea that is about 6 percent lower than the even model. An equivalent analysis carried out for small auklets showed a 2 percent decline in the estimate of the number of carcasses lost at sea. These results indicate that at-sea loss estimates are robust to the density distributional model used, and that the assumption of an even distributional pattern is an acceptable alternative to the OCSEAP based model.

Obviously, the likelihood that a carcass will float for only a short period of time before beaching is greater if a bird is contacted by oil close to shore. Some seabird species are seldom found beyond the nearshore zone, and we assume that dead or injured members of these species will come ashore before sinking can occur. These species groups include loons, grebes, sea ducks, and some species of murrelet.

6.5 Summary of Model Processes

Estimating the actual mortality of seabirds from the records of the carcasses recovered is done using a computer program to implement the methodologies described previously. The program proceeds by reading one record from the morgue data base, and sequentially estimating the number of birds not counted due to scavenging, the number of birds not counted to due to incomplete coverage by searchers, and the number of birds lost at sea. Because these computations are dependent on knowing the location where the birds were recovered, the total number of birds without location data are summed for each morgue, but no attempt is made to estimate the loss associated with these records. When the entire data base has been processed, an overall correction factor is calculated for records from each morgue and applied to those records without specific locations. The computer analysis designed to generate the best estimate of overall mortality proceeds as follows:

(1) Compute the proportion of depositable coastline searched, P*, for each 15′ cell using equation 6.3 (1). These calculations are made on a cell-by-cell basis and remain fixed throughout the model run.

(2) Read a record from the morgue data base. Data fields are "date of processing," "species code," "number of carcasses recovered," "15′ cell identifier," "sector identifier," "latitude," "longitude," "logical flag for recovery from the water rather than the beach," and "morgue identifier." If latitude and longitude are undefined, add the number of carcasses recovered to the running total of such carcasses for the current morgue and go back to (2).

(3) If the species is not a murre species, and the date of processing minus the estimated lag time between recovery and processing is later than the cutoff date for oil-induced mortality, go to (2).

(4) For the Barren Islands, or for carcasses recovered in the water, ignore this step. Use equation 6.2 (4) to estimate the number of carcasses that would have been recovered were it not for loss due to scavenging. Cr is the number of carcasses recovered from the database record read in (2), m is the estimated intersearch interval for a given sector, and Ss is the empirically estimated likelihood that a

carcass will persist a given number of days on the beach in spite of scavenging. The result of this calculation is the number of carcasses deposited on the beach prior to scavenging, Cb.

(5) For carcasses recovered in the water, ignore this step. Use equation 6.3 (3) to estimate the number of carcasses that were beached taking, into account incomplete search effort. The value of P* specific to the current 15′ cell computed in (1), and Cb*, the number of carcasses deposited on the beach before scavenging computed in (4), are used as inputs. The result is Cs, the number of carcasses deposited on the beach after taking into account the effects of both scavenging and search effort.

(6) For species with inshore distributions, or if the carcasses were recovered inside Prince William Sound, this section is ignored. Use equation 6.4 (5) to estimate the number of carcasses that would have come ashore were it not for loss at sea. Use Cs from (5) as the estimate of Cb*; S is an empirically derived function based on the Kodiak drift experiments (releases 5-8) fitted using the methodology in appendix E. The variable B is estimated as follows:

(A) If the date of beaching — estimated as the date of processing minus the lag time between recovery and the date of processing — is during April, and the species is a murre species, B is calculated using the OCSEAP distribution of murres for April and May intersected with the paths of Lagrangian elements from the HAZMAT model that beached in the current 30′ cell on that date. If the date is later, then it is assumed that all Lagrangian elements beaching in the current 30′ cell intersected a constant density of murres on each day from 1 May onward. The constant density encountered is assumed to be different depending on whether the beaching site from (2) was located on the eastern or western side of Kodiak Island or the area north of Kodiak Island.

(B) If the species is an auklet species, the method of (6A) is used except that the OCSEAP distribution of auklets is used.

(C) If the species is not a small auklet or a murre species, a constant density is assumed to have been encountered from 30 March to the time of beaching.

(7) Collect sums of numbers of birds missing due to scavenging, search effort, and loss at sea. Sums are collected separately for each sector and morgue.

(8) If all the records in the morgue data base have not been read, return to (2) and repeat (2)-(8).

(9) For each of the different morgues, divide the number of carcasses missing (the sum from (7)) by the number of carcasses recovered with locations. Multiply this by the number of carcasses in the current morgue that were not associated with a location.

(10) Output results.

6.6 Other Factors Affecting Carcass Loss

Several factors known to result in undercount of carcasses were not taken into account explicitly because necessary data were lacking. These factors are (1) rewash of carcasses, (2) burial of carcasses, (3) carcasses missed by searchers, and (4) carcasses drifting out to sea. Factors (1), (2), and (3) relate to processes that would occur on the beach face as alternatives to scavenging. Taking these factors into account would have a major effect on the results only to the extent that the rates of these processes greatly exceed that of scavenging. At this point we do not know if this is the case, and we opt for the simplicity of considering only the one factor. It is possible that one of these factors could significantly increase the estimated mortality if appropriate data were available for Alaska. Additionally, some of the carcasses that had drifted as far south as Tugidak Island or Perryville on the Alaska Peninsula may have been been directed back out to sea. It may be possible to determine this in the future based on results of oceanographic studies or further trajectory analysis.

6.7 Sensitivity Analysis and Model Inputs

Model calculations require a large number of input variables, some of which can only be estimated with a good deal of uncertainty. To evaluate the variability in model results occurring as a consequence of this uncertainty, we used a Monte Carlo procedure to simulate the effects of uncertainty on model outcomes. The model was run 1,250 times; for each run a value was randomly selected from an appropriate probability distribution for each of the parameters considered to be a source of significant uncertainty. Repeated measurements of these variables are not available for most input parameters. In these cases, we model the probability density function of parameter values as a triangular distribution where the vertices of the triangle are defined by the minimum estimate of the parameter value, the best estimate, and the maximum estimate (Ford et al., 1982). This methodology was not used to model the probability density of the parameters defining the Weibull distribution, b_0 and b_1 (see appendix E), which are known to be normally distributed. In the case of the scavenging rate function, there is minimum, best, and maximum estimate of Ss_j for all j, but the Ss_j cannot be considered to be independent. In this case, we sample from the probability density function for each j using the same uniform random deviate so that all the Ss_j will tend to be high or low simultaneously. Table 6-3 contains a summary of model input values, including best estimates and ranges.

We used an additional method of examining model sensitivity that shows the variation in model results based on extreme values of each parameter or set of parameters. For this

TABLE 6-3. Summary of model input values. Best-estimate values and ranges are given, where appropriate. Sources of values are given in brackets. Variable names are given in parentheses.

MORGUE DATA RECORDS [USFWS]

COLLECTION DATE CUTOFF FOR NON-MURRES

Best Estimate: 1 July 1989 [This Study]

MEAN INTERVAL BETWEEN COLLECTION AND PROCESSING

Best Estimate: 14 days [Piatt et al. 1990] Range: 7-14 days

PERSISTENCE ON THE BEACHFACE (Ss_j)[1]

Day	Best Estimate of Proportion Remaining	Day	Minimum and Maximum Proportion Remaining
0	1.000	0	1.000-1.000
1	0.759	1	0.544-0.833
2	0.381	2	0.087-0.519
3	0.301	3	0.087-0.417
4	0.198	4	0.044-0.333
5	0.178	5	0.000-0.333
6	0.083	6	0.000-0.250
33	0.000	33	0.000-0.163
99	0.000	99	0.000-0.000

TABLE 6-3. (Cont'd.)

SHORELINE TYPE CHARACTERISTICS [ESI, Interviews]

	Reflective (R_k)	Proportion Walkable (Pw)[2] Best Est.	Proportion Walkable (Pw)[2] Range
Exposed Rocky Shores	Yes	0.00	--
Sheltered Rocky Shores	Yes	0.00	--
Exposed Wavecut Platform	No	0.50	0.20-0.80
Fine/Medium Grain Sand	No	1.00	--
Coarse Grain Sand	No	1.00	--
Mixed Sand/Gravel	No	1.00	--
Gravel	No	0.50	0.20-0.80
Exposed Tidal Flat	No	1.00	--
Sheltered Tidal Flat	No	0.00	--
Marsh	No	0.50	0.00-1.00
Ice	Yes	0.50	0.00-1.00
Unclassified	Yes	0.00	--

SEARCH EFFORT CHARACTERISTICS [Interviews]

	Proportion of Walkable Beach Searched (Ps)[3] Best Est.	Proportion of Walkable Beach Searched (Ps)[3] Range	Frequency of Search (Days) (m)[4] Best Est.	Frequency of Search (Days) (m)[4] Range
Prince William Sound	0.85	0.70-1.00	3.0	2-4
Kenai Peninsula	1.00	--	9.0	7-11
Cook Inlet	1.00	--	3.0	2-4
Barren Islands	1.00	--	7.5	--
Katmai NP	0.80	0.70-0.90	8.0	7-9
Becharof NWR	0.95	0.90-1.00	37.5	30-45
Aniakchak NM	1.00	--	8.0	6-10
Kodiak Island	0.75	0.50-1.00	9.0	7-9
Alaska Pen. NWR	0.52	0.05-1.00	37.5	30-45

TABLE 6-3. (Cont'd.)

OCSEAP DISTRIBUTIONAL DATA [NODC, USFWS]

Used for Murres and Auklets Only

LOSS AT SEA FUNCTION [This Study]

	Expectation	Variance
Estimate of Scale Parameter, λ, of Weibull Distribution (b_0)	-7.67	.0409
Estimate of Shape Parameter, γ, of Weibull Distribution (b_1)	3.09	.0075

[1] Minimum and maximum ranges of the four studies discussed in section 5.4. The best estimate is the mean over all studies for a given number of days on the beach.

[2] Estimates derived from interviews with agency personnel and others familiar with the various areas and knowledgeable with regard to the search effort (see section 5.2). For Prince William Sound, gravel beaches and sheltered rocky shores were considered walkable (this assumption is based on interview responses). Very little information was available on walkability of ice or marsh.

[3] Estimates derived from interviews with agency personnel and others familiar with the various areas and knowledgeable with regard to the search effort (see section 5.2). The values for the Kodiak and Alaska Peninsula sectors are the least well known. Cook Inlet was considered similar to Prince William Sound in the search effort. It might be possible to refine our knowledge of this parameter for all sectors from the logbooks.

[4] Estimates derived from interviews with agency personnel and others familiar with the various areas and knowledgeable with regard to the search effort (see section 5.2). The values for the Kodiak and Alaska Peninsula sectors are the least well known. Cook Inlet was considered similar to Prince William Sound, Kodiak was considered similar to Katmai, and the Alaska Peninsula area was considered similar to Becharof in search frequency. It might be possible to refine our knowledge of this parameter for all sectors from the logbooks.

analysis, all model inputs were held at their best estimates except for one that was set at either its maximum or minimum value. We used the parameter ranges from table 6-3 except for the parameters of the fitted Weibull distribution. In that case, we used the relatively rapid sinking rates observed for release AK-8.

7.0 RESULTS AND CONCLUSIONS

7.1 Results

For a carcass to have been logged into a morgue, three events must have occurred:

(1) The carcass must have drifted ashore before it decomposed to the point where it sank or was consumed by scavengers at sea.

(2) The carcass must not have been consumed or carried away by scavengers on the beach where it was cast up.

(3) Searchers must have come to the beach where the carcass was deposited and seen and collected it.

The basic structure of the model is therefore essentially multiplicative. The probability of recovering a carcass would be the probability that all three events occurred — the product of the probabilities of the three events. For example, if there were a 50 percent chance of a carcass persisting through each of the three processes, then the likelihood of persisting through all three would be 0.50 x 0.50 x 0.50 = 0.125. In other words, 1 out of 8 carcasses would have been recovered.

Using our best estimates of the input parameters, we found that the probability of a carcass beaching before it sank was 42 percent, that the probability it would not have been scavenged beyond recognition or removed from the beach before searchers arrived was 31 percent, and that the probability searchers would have actually encountered and recognized the remains was 59 percent. The joint probability of all of these events would be 8 percent, implying that about 375,000 seabirds died as a result of the *Exxon Valdez* oil spill.

Results of the sensitivity analysis (figure 7-1) show that taking uncertainty in parameter values into account tends to skew model results toward higher estimates of mortality. This skew occurs partly because the interactions of the model processes are multiplicative, and partly because uncertainty in some parameters is skewed in a direction that increases the estimate of mortality. The mean estimate of mortality based on the Monte Carlo version of the model is about 435,000 birds. The fifth percentile of the results of the Monte Carlo version of the model, i.e., the 5 percent lower limit on model results, is 300,000, and the ninety-fifth percentile is 645,000. These are not true confidence limits, but rather are based on our estimates of the nature of the variability in model inputs.

The results of varying one set of input parameters at a time are presented in table 7-1. These results are useful in determining the relative contributions of various model inputs to overall model uncertainty but we consider these extreme parameter values to be unlikely. The factor most strongly influencing the estimate of direct mortality was the rate of scavenging of beached carcasses that determined persistence on the beach face. Use of the lower or upper bounds on this parameter resulted in a decrease of 38.1% or an increase of 105.4% in the estimate of direct mortality. In terms of increasing the mortality estimate, the next most important source of uncertainty was the proportion of the walkable beaches searched (9.7%), and the lag in the time between carcass retrieval and processing. In terms of decreasing the mortality estimate, the next most important source of uncertainty was the loss rate at sea (24.3%), the proportion of the walkable beaches that were search (15.6%), the proportion of beaches that were walkable (13.4%), the frequency at which beaches were searched (10.3%), and the lag in the time between carcass retrieval and processing (8.7%). These results indicate that further study of processes that occur on the beach face would be of use in refining estimates of direct mortality.

Estimates of the degree of undercounting vary widely among the geographic regions affected by the spill. Based on the best estimates of the input parameters, the highest recovery rates would have occurred in Prince William Sound (35 percent) and at the Barren Islands (49 percent). These relatively high recovery rates resulted because most of the birds

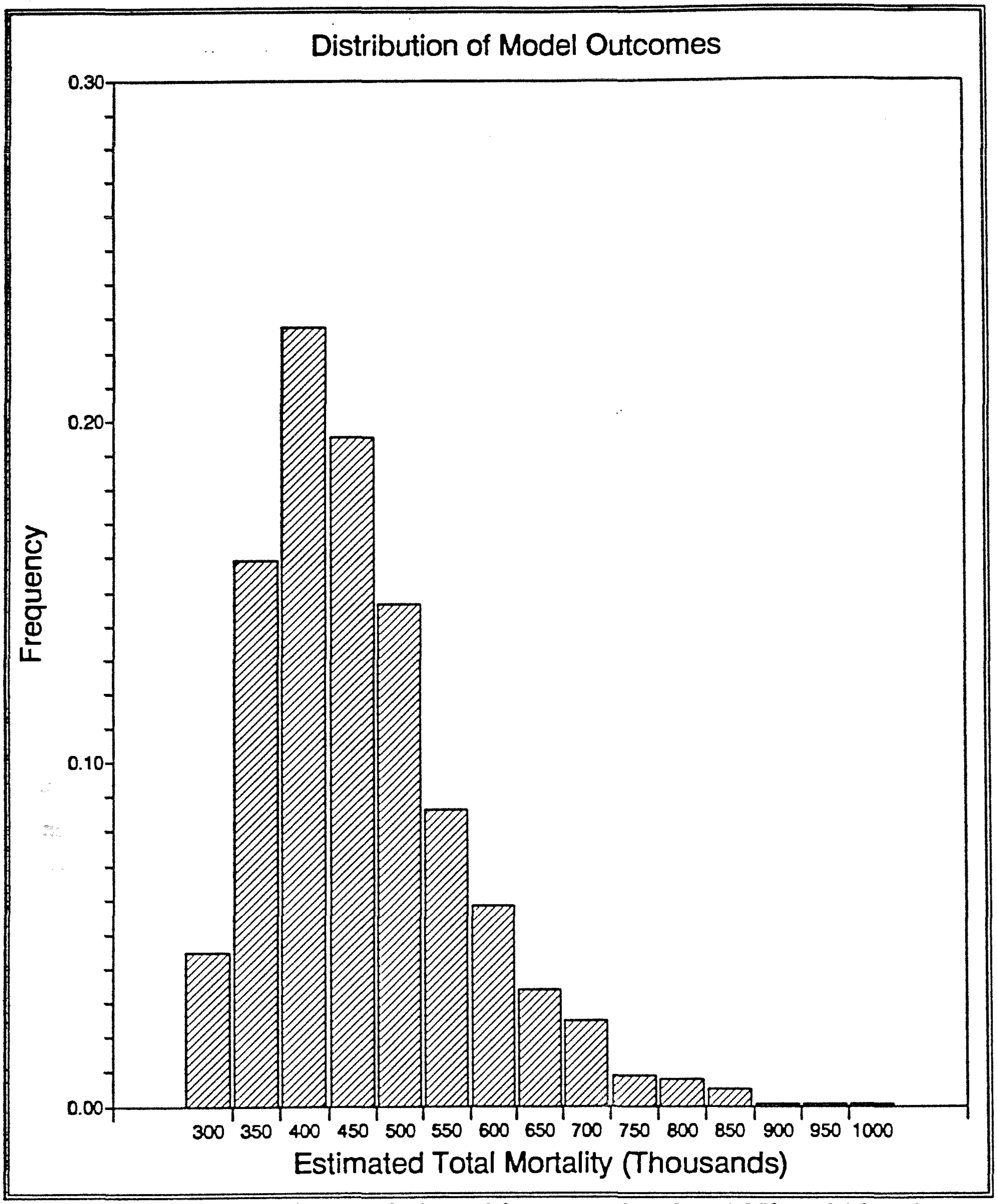


FIGURE 7-1. Distribution of Monte Carlo model outcomes based on 1,250 model iterations. Input parameters were randomly selected for each iteration based on a range of possible values.

TABLE 7-1. Effects on model results due to varying one input parameter at a time while holding other parameters at their best estimate values.

PARAMETER	LOW ESTIMATE OF MORTALITY		HIGH ESTIMATE OF MORTALITY	
Collection/Processing Interval	343,963	(91.3%)	395,016	(104.8%)
Persistence on the Beachface	233,441	(61.9%)	773,857	(205.4%)
Proportion Walkable	326,191	(86.6%)	472,167	(125.3%)
Walkable Proportion Searched	318,192	(84.4%)	515,877	(136.9%)
Frequency of Beach Searches	337,840	(89.7%)	413,444	(109.7%)
Loss at Sea Function	285,073	(75.7%)	432,491	(114.8%)

in these areas beached relatively early, with relatively little time for loss at sea. In addition, we assumed that the absence of mammalian scavengers on the beaches of the Barren Islands would have resulted in little loss due to scavenging, although avian scavenging certainly occurred. Cook Inlet (21 percent) and Kenai Fjords National Park (14 percent) had intermediate recovery rates, and Kodiak Island (6 percent) and the Alaska Peninsula (2 percent) had the lowest recovery rates. The low recovery rates on Kodiak Island and the Alaska Peninsula result from the long periods of time that carcasses would have been at sea before beaching, and the relatively low level of search effort.

7.2 Conclusions

Piatt et al. (1990) estimated that the total direct mortality of seabirds resulting from the *Exxon Valdez* was in the 100,000-300,000 range. This estimate was based on preliminary data and on comparison with mortality estimates for several other spills. The recovery rate for birds killed by the *Exxon Valdez* spill was probably unusually low for several reasons.

Peninsula. To recover dead birds, searchers had to cover vast stretches of coastline, most of which was accessible only from the sea. Under more typical conditions, bird recovery workers gain access to beaches by road or often even live adjacent to the affected beaches. Second, oil from the *Valdez* continued to wash ashore for months, and dead seabirds continued to wash ashore with it. Because the spill was unusually long by comparison with most spills, carcasses of seabirds were at sea longer and were more likely to decompose to the point where they sank. Finally, the density of scavengers in coastal Alaska is far higher than on most beaches where oil spills have occurred, and must have resulted in an unusually large number of carcasses being removed from the beach face before recovery personnel could reach them. Based on our analysis, we would place the mortality from the *Exxon Valdez* in the range of 300,000-645,000, with a best approximation of 375,000-435,000 total mortality. This estimate reflects only direct mortality occurring in the months following the spill, and does not address chronic effects or loss of reproductive output.

APPENDIX A:
LOCATIONS OF BIRD CARCASS COLLECTIONS AND THEIR LATITUDE/LONGITUDE COORDINATES

The following list is a compilation of place names and latitude/longitude coordinates used in the construction of the final morgue data base to indicate the locations of bird carcass collections. Variations in spellings have been retained.

Place Name	Latitude	Longitude	Place Name	Latitude	Longitude
3-Hole B	59.7500	149.6333	Alitak	56.8421	154.2932
ANDERSON B	53.7000	166.8500	Alitak B	56.8810	154.1251
AYAKULIK R	57.2000	154.5333	Aliulik Peninsula	56.8322	153.9445
Afognak	58.2598	152.5642	Alligator I	58.4667	152.7833
Afognak B	58.0360	152.6647	Alnichak	57.8094	155.2184
Afognak I	58.2598	152.5642	Amalik B	58.0804	154.5300
Afognak I (N)	58.4541	152.5614	Amatuli C	58.9187	152.0100
Afognak I (NW)	58.4039	152.8354	Amatuli Is	58.9166	152.0021
Afognak Strait	57.9855	152.8040	Amber B	56.8122	157.3583
Afognak Village	58.0098	152.7700	Anchor B	59.7904	151.8728
Agnes	59.7785	149.5873	Anchor P	59.7904	151.8728
Agnes C	59.7785	149.5873	Anchor Pt	59.7770	151.8837
Aguliak I	60.3705	147.8661	Anchor R	59.7904	151.8728
Aialik	59.9411	149.7569	Anchorage B	56.3098	158.3909
Aialik B	59.7961	149.7171	Anchorcoal	59.6791	151.7334
Aialik Cape	59.7080	149.5319	Andreon	58.5170	152.4148
Aicallisto	59.8250	149.6309	Anges C	59.7785	149.5873
Akhiok	56.9417	154.1524	Aniackchak	56.7135	157.5128
Akliak B	59.7961	149.7171	Aniakchak	56.7135	157.5128
Aleut Village	58.0279	152.7566	Aniakchak B	56.7135	157.5128
Alexander P	55.8833	159.1667	Aniakshak	56.7135	157.5128
Aligo Pt	59.6440	149.7488	Anianchak	56.7135	157.5128
Alinchak	57.8094	155.2184	Anilchik B	57.8094	155.2184
Alinchak B	57.8094	155.2184	Anisom Pt	59.5333	151.4500
Alinchik B	57.8094	155.2184	Anton Larsen B	57.8724	152.6291

Place Name	Latitude	Longitude	Place Name	Latitude	Longitude
Alinchak B	57.8094	155.2184	Antones	57.8854	152.6542
Antonnes	57.8854	152.6542	Bear Glacier Beach	59.9220	149.5382
Antons	57.8854	152.6542	Bear I	59.7328	151.0592
Antons I	57.8854	152.6542	Beauty B	59.5339	150.6337
Applegate I	60.6236	148.1500	Beauty Bay Beach	59.5436	150.6504
Applegate Rk	60.3530	147.3900	Beluga Slough	61.3025	150.7025
Attialik B	59.7961	149.7171	Berger B	59.3440	150.7620
Aurora Lagoon	59.7037	151.1081	Big B	58.5647	152.6003
Ayakulik R	57.2000	154.6833	Big Fort	58.5002	152.4298
BAN I	58.3167	152.8833	Big Fort I	58.5002	152.4298
Back B	58.0815	152.7699	Big Waterfall B	58.4296	152.5049
Badger Core	59.1974	151.4655	Bishop Rock	60.1042	147.8875
Bainbridge I	60.0992	148.1600	Bishops Beach	61.3025	150.7025
Bainbridge Passage	60.1326	148.1900	Black B	59.5234	150.2388
Bainbridge Pt	60.2011	148.0500	Black Cape	58.4116	152.8858
Barabara Pt	59.4840	151.6486	Black Lagoon	59.2232	151.5127
Bare B	57.9578	153.0750	Bligh I	60.8326	146.7700
Bare I	57.9578	153.0750	Blue Fiord	60.4668	148.2500
Barren I	58.9063	152.1420	Blue Fox B	58.4492	152.6978
Barren Islands	58.9063	152.1420	Bluefox B	58.4492	152.6978
Barwell I	59.8589	149.2855	Bluff Pt	59.6594	151.6800
Bay of Isles	60.3968	147.6800	Blying Sound	59.8231	149.1657
Bear B	57.8615	155.2250	Bootlegger C	61.2046	149.9241
Bear B (Mainland)	57.8615	155.2250	Bootlegger Harbor	61.2046	149.9241
Bear C (H)	59.7304	151.0409	Bootleggers C	61.2046	149.9241

Place Name	Latitude	Longitude	Place Name	Latitude	Longitude
Bear C (S)	59.7947	149.6479	Bootleggers H	61.2046	149.9241
Bear Glacier	59.9420	149.5430	Bovy B	59.2017	151.4988
Broad Pt	57.6926	152.3989	Cape Mansfield	59.9474	149.0329
Burger B	59.3440	150.7620	Cape Newland	58.5106	152.6554
Buskin R	57.7613	152.4918	Cape Ninilchik	60.0166	151.7218
CAMP I	57.3667	154.0250	Cape Nukshak	58.4012	153.9840
CANNERY C	57.1583	154.2250	Cape Paramanof	58.3120	153.0500
CHAI CHI I	55.8500	159.2000	Cape Ressurection	59.8689	149.2878
Cabin B	60.6704	147.4700	Cape Ressurrection	59.8689	149.2878
Caines Head	59.9833	149.3972	Cape Resurrection	59.8689	149.2878
Callisto Head	59.9198	149.4799	Cape Starichkof	59.8844	151.8020
Cape Aklek	57.6638	155.6004	Cape Tolstoi	58.4001	152.1305
Cape Alitak	56.8421	154.2932	Cape Uganik	57.9570	153.5288
Cape Chiniak	58.5270	153.9041	Cape Ugat	57.8761	153.8444
Cape Chiniak (Kodi)	57.6062	152.1571	Cape Ugyak	58.2781	154.1110
Cape Chiniak (Main)	58.5270	153.9041	Cape Uyak	57.6439	154.3400
Cape Cleare	59.7712	147.9100	Carry Inlet	58.5883	152.5390
Cape Douglas	58.8434	153.2538	Carsham Pt	58.6344	152.4560
Cape Grant	57.4322	154.7111	Chad I	59.6959	149.5667
Cape Greville	57.5960	152.1513	Chankliut I	56.1503	158.1470
Cape Gull	58.2126	154.1558	Channel I	60.2914	147.4100
Cape Ikolik	57.2896	154.7899	Chat C	59.7227	149.5700
Cape Karluk	57.5832	154.5096	Chat I	59.6959	149.5667
Cape Kazakof	58.0778	152.6307	Chatham B	59.2040	151.7934
Cape Kostromitinof	58.0820	152.5478	Cheif Pt	57.7100	153.9064

Place Name	Latitude	Longitude	Place Name	Latitude	Longitude
Cape Kuliak	58.1462	154.2138	Chenega I	60.3266	148.0600
Cape Kuliuk	57.8066	153.9369	Chenik	59.2174	154.1410
Chenik Head	59.2080	154.1198	Cliff Pt	57.7297	152.4435
Cheval I	59.7787	149.5180	Cloudy Cape	59.5874	150.0957
Chiachi I	55.8500	159.2000	Coal	59.6496	151.3914
Chief C	57.7170	153.9060	Coal B	59.6496	151.3914
Chief Pt	57.7100	153.9064	Coal Pt	59.6138	151.4242
Chignik	56.2965	158.3838	Coleman B	59.8713	149.6632
Chignik B	56.3768	158.2522	Colman B	59.8713	149.6632
Chignik Lagoon	56.3148	158.5544	Cook Inlet	59.0653	152.6299
China Poot B	59.5623	151.2927	Course Pt	57.8956	152.4680
Chinaik	57.7148	152.2846	Crafton I	60.5017	147.9400
Chiniak	57.7148	152.2846	Crag Pt	57.8829	152.6754
Chiniak B	57.7148	152.2846	Crater B	59.7075	149.8075
Chiswell I	59.6000	149.5668	Cronin I	59.4833	151.5166
Chiswells	59.6343	149.6406	Crooked I	57.7742	152.3942
Chrome B	59.2080	151.8240	Culross I	60.7012	148.1900
Chugach	59.1884	151.5832	Culross Pass	60.6833	148.2333
Chugach B	59.1884	151.5832	Dakavak B	58.0498	154.6924
Chugach I	59.1246	151.4688	Dakovak B	58.0498	154.6924
Chugach Pass	59.1534	151.7708	Danger I	59.9257	148.0800
Chugach Passage	59.1534	151.7708	Dangerous Passage	60.3623	148.1000
Chugagrew	59.6830	151.1345	Dark I	58.6458	152.5513
Chughch	59.1884	151.5832	Day Harbor	59.9739	149.1677
City Beach	60.1000	149.4333	Daylight H	58.4874	152.5776

Place Name	Latitude	Longitude	Place Name	Latitude	Longitude
Clam C	59.2166	151.8333	Daylight Harbor	58.4874	152.5776
Cliff B	59.7216	149.6000	Delphin B	58.3721	152.4757
Discoverer B	58.3368	152.3931	Elrington I	59.9715	148.0900
Discovery B	58.3368	152.3931	Elrington Passage	60.0092	148.0800
Discovery Pt	60.2444	147.7000	English B	59.3575	151.9416
Disk I	60.4932	147.6500	Entrance I	60.5134	147.5893
Division I	59.4200	150.6883	Eshamy B	60.4622	148.0000
Dogfish B	59.2422	151.9173	Evans I	60.0770	148.0400
Dora Pass	59.6723	149.7183	Evans I (NW)	60.1139	148.0300
Dora Passage	59.6723	149.7183	Evans Pt	60.1325	147.9100
Douglas R	59.0548	153.7615	Ewan B	60.3776	148.1300
Drier B	60.3105	147.8300	Falls B	60.5229	148.0000
Driftwood B	59.9221	149.2507	Fault Pt	59.9645	149.1319
Dry B (AP)	57.6336	155.7470	Flat I	59.3297	151.9999
Dry B (KP)	59.6683	153.1307	Flemming I	60.1663	148.0200
Dry C	57.6336	155.7470	Foul B	58.3402	152.8314
Dry Creek	57.7470	155.6211	Foul B	60.5833	148.0667
Duck B	58.1138	152.4387	Foul Passage	60.5000	147.6375
Duck Cape	58.3854	152.2344	Fourth of July Creek	60.0920	149.3784
EGG I	56.8931	154.2167	Fox B	57.9821	152.7574
Eagle Cape	58.5470	152.6688	Fox I	59.3550	150.3733
Eaglek B	60.8595	147.7300	Fritz Creek	59.6820	151.3683
Eaglek I	60.8170	147.7222	Geese Channel	56.7547	153.8694
East Amatuli	58.9166	152.0000	Gesse Channel	56.7547	153.8694
East Amatuli I	58.9133	151.9935	Gibbon Anch	60.2842	147.4100

Longitude	Place Name	Latitude	Longitude	Place Name	Latitude
Eldorado Narrows	59.8998	149.3244	Gibson C	57.7784	152.4486
Eleanor I	60.5458	147.5800	Glacier Spit	59.6500	151.1166
Eleanor I (E)	60.5557	147.5500	Gore Beach	59.1952	150.9606
Elizabeth I	59.1554	151.8340	Gore Pt	59.1952	150.9606
Granite B	60.4221	147.9900	Goreyalik	59.3468	150.8489
Granite C	59.6113	149.7619	Hidden B	60.7040	148.1300
Granite I	59.6508	149.8166	Hive I	59.8873	149.3780
Granite Pa	59.6434	149.7778	Hog I	58.0026	152.6776
Granite Passage	59.6434	149.7778	Hogan B	60.1960	147.7600
Grants Lagoon	57.4322	154.7111	Home C	59.3911	150.7116
Graveyard Pt	60.3334	147.2100	Homer	59.6461	151.4812
Green I	60.2664	147.4100	Homer Harbor	59.6409	151.4341
Grewanisom Peterson	59.5833	151.3000	Homer Spit	59.6255	151.4510
Gull I	59.5821	151.3340	Hoof Pt	59.4166	150.3000
HELEN BAY BEACH	57.7764	152.2417	Hook B	56.5109	158.1218
Halibut B	57.3934	154.7216	Hook P	56.5109	158.1218
Halibut C	59.6089	151.2230	Horseheads B	59.9500	149.1666
Hallo B	58.4330	154.0044	Horseshoe B	60.0191	147.9366
Hallo Cr	58.4330	154.0044	Horseshoe B	60.0212	147.9400
Harbor I	59.6762	149.6739	Hub Rock	59.7230	149.7332
Harding Gateway	59.8019	149.4437	Humpy C	59.9682	149.3186
Hardover Pass	59.4131	150.6613	Icon B	57.8981	152.3361
Harrington Pt	59.4533	150.4998	Icy B	60.2628	148.2600
Harris B	59.7107	149.8886	Ingot I	60.5136	147.6300
Hartman I	57.3676	156.3034	Ishut B	58.1717	152.2408

Place Name	Latitude	Longitude	Place Name	Latitude	Longitude
Harvester I	57.6591	154.0006	Island B	57.9563	152.4202
Harvister I	57.6591	154.0006	Islut B	58.1717	152.2408
Hawkins I	60.5167	146.0833	Izhut B	58.1717	152.2408
Herring B	60.4591	147.7400	Jackpot B	60.3418	148.2100
Hesketh I	59.5085	151.5167	James Lagoon	59.5786	150.4156
Johnson B	59.9324	148.7642	Katmai B	57.9884	154.9749
Johnson B	60.3470	147.8400	Katmi	57.9884	154.9749
Johnstone B	59.9324	148.7642	Katmia	57.9884	154.9749
Junction I	60.3902	148.0000	Kekur Pt	57.8638	152.7839
Jute B	57.5439	155.8357	Kenai Pe	59.4062	151.2120
KNEE B	57.9333	152.4167	Kenai Peninsula	59.4062	151.2120
KNOLL B	56.9500	153.5833	Kiavak B	57.0178	153.5801
KULIAK	57.8066	153.9369	Kiliuda B	57.3008	152.9534
Kachemak B	59.6454	151.3013	Kilter P	59.3597	150.4040
Kaflia	58.2582	154.1779	Kinak B	58.1320	154.4444
Kaflia B	58.2582	154.1779	King C	58.1966	152.0266
Kaguyak B	56.9060	153.6594	Kitoi B	58.1875	152.3420
Kalrose Pass	60.6833	148.2333	Kitten P	59.3597	150.4040
Kalsin B	57.6312	152.4094	Kitten Pass	59.3550	150.3733
Kalsin Reef	57.6312	152.4094	Kiukpalik I	58.6080	153.5598
Kalsin Reef	57.6834	152.3002	Kizhuyak B	57.8424	152.8606
Kamishak B	59.1690	153.9506	Kizhuyak B (Head)	57.7309	152.8616
Kanatak	57.5722	156.0356	Kizhuyak Pt	57.9221	152.6291
Karluk	57.5772	154.4516	Kizhyak B	57.8424	152.8606
Karluk Lagoon	57.5771	154.4436	Knight I	60.3333	147.7300

Place Name	Latitude	Longitude	Place Name	Latitude	Longitude
Kashvik B	57.9406	155.0800	Knight I (W)	60.3298	147.8800
Kasitsna	59.4753	151.5741	Knowles Head	60.6858	146.6600
Kasitsna B	59.4753	151.5741	Kodiak	57.7926	152.4179
Kasitsna B	59.4833	151.5333	Koyuktolik B	59.2422	151.9173
Katmai	58.0269	154.9328	Kuale B	57.7397	155.5639
Kujulik B	56.6063	157.8690	Malina B	58.2186	153.0765
Kukak	58.3197	154.2322	Malina Pt	58.0427	153.3424
Kukak B	58.3197	154.2322	Marmat S	58.2558	151.9230
Kuliak B	58.1790	154.2428	Marmot B	58.0370	151.9692
Kupreanof Strait	57.9911	153.1361	Marmot I	58.2177	151.8455
Kupreanof Strait (W)	58.0210	153.2989	Marmot I (SW of)	57.9384	152.2150
Kupreanot Strait	57.9911	153.1361	Marmot Strait	58.2210	151.9350
Larsen B	57.5350	154.0258	Marmot Strait	58.2558	151.9230
Larson B	57.5350	154.0258	Marsha B	60.3376	147.6800
Latouche I	60.0058	147.9200	Mary Anderson C	58.1332	152.4466
Latouche Passage	59.9890	148.0200	Mary B	59.8487	149.3986
Latouche Village	60.0512	147.9100	Mary I	57.7069	152.5333
Lighthouse Pt	58.4853	152.6605	Marys B	59.8487	149.3986
Little Fort I	58.5126	152.3994	Masked B	60.3613	148.0300
Little Green I	60.2023	147.5100	Matushka I	59.6185	149.6411
Little Smith I	60.5196	147.4300	Matuska	59.6166	149.6166
Lone I	60.6788	147.7600	McArthur C	59.4456	150.3545
Long I	57.7729	152.2773	McArthur P	59.4625	150.3356
Louis B	60.4751	147.6700	McCarty Fiord	59.5152	150.4103
Low Cape	56.9903	154.5234	McDonald Spit	59.4883	151.5833

Place Name	Latitude	Longitude	Place Name	Latitude	Longitude
Lowell Pt	60.0666	149.4331	McKeon Spit	59.5500	151.4000
Lower Passage	60.5094	147.6600	McMullen C	59.7666	149.7666
MacArthur P	59.4625	150.3356	Mears Point	60.6542	147.9292
Macsurok	59.5322	150.1836	McNeil R	59.1102	154.2597
Main B	60.5441	148.0600	Metrofania	55.8667	158.8000
Middle Cape	57.3560	154.7893	Midarm I	58.1858	152.3283
Mill B	57.8287	152.3459	Middle B	57.6797	152.4605
Millers Landing	59.6666	151.4333	Neketa B	58.5326	152.6348
Miners Pt	57.9026	153.7254	Nelson I	57.8930	152.4095
Missak	58.1324	154.3099	Newman B	57.1000	153.3667
Missak B	58.1324	154.3099	New Year Is	60.3144	147.9200
Mitrofania I	55.8667	158.8000	Ninilchik	60.0616	151.6660
Monashka B	57.8393	152.4070	Noisy I	57.9194	153.5588
Montague I	60.0252	147.4800	Northwest B	60.5654	147.5900
Montague Pt	60.3797	147.1000	Northwestern Fiord	59.7342	149.9146
Moran Beach	59.7333	149.9166	Nuka	59.3528	150.6825
Morning C	59.4551	150.3136	Nuka B	59.4258	150.5085
Morraine Bch	59.7333	149.9166	Nuka I	59.3528	150.6825
Mud B	59.6358	151.4883	Nuka Pass	59.3386	150.8143
Mullen C	59.7666	149.7666	Nuka Passage	59.3386	150.8143
Mummy B	60.2212	147.8200	Nuka Pt	59.2888	150.7123
Mummy I	60.2877	147.9100	Nukshak	58.4012	153.9840
N61 4.5 W147 52.0	61.0750	147.8700	Nyman Peninsula	57.7382	152.5088
Nachalni	57.9756	152.9356	OUTLET CAPE	57.9986	153.2833
Nachalni I	57.9756	152.9356	Ocean B	57.0835	153.1820

Place Name	Latitude	Longitude	Place Name	Latitude	Longitude
Naked I	60.6568	147.4100	Oil Creek	57.6502	155.6947
Naked I (NE)	60.6748	147.3400	Onion B	58.0593	153.2450
Narrow Cape	57.4248	152.3301	Outer I	59.3518	150.4030
Natoa I	59.6474	149.6176	Ouzinkie	57.9222	152.5047
NE HARBOR	57.6306	154.3500	PIVOT PT	57.3000	153.0167
Near I	57.7793	152.4034	Paddy B	60.3944	148.0800
Paramanof B	58.3026	152.9323	Paguna Arm	59.6631	150.0892
Paramanoff B	58.3026	152.9323	Paradise C	59.7550	149.6050
Paramoanoff	58.3026	152.9323	Petrof Pt	59.2883	150.7550
Parammof B	58.3026	152.9323	Petrof Pt	59.3740	150.7716
Party Cape	58.6246	152.5666	Phoenix B	58.4144	152.3225
Pasagshak	57.4462	152.4838	Picnic Harbor	59.2550	151.4166
Pasagshak B	57.4462	152.4838	Pillar Cape	58.1508	152.1136
Passage Pt	60.5149	147.6900	Pillar Cr	58.1508	152.1136
Paul s B	58.4003	152.3622	Pilot B	59.5833	150.5000
Paule B	57.7397	155.5639	Pilot Harbor	59.5833	150.5000
Pauls B	58.4003	152.3622	Pilot Rock	59.7417	149.4667
Peak I	60.7017	147.3800	Pleiades Is	60.2273	148.0100
Pedersen Glacier	59.8796	149.7420	Pogiadam	59.3421	151.9732
Perenosa B	58.3777	152.4153	Pogibshi Pt	59.4287	151.8759
Perenosa B	58.4438	152.4282	Point Adam	59.2584	151.9865
Perevalnie Passage	58.6380	152.3708	Point Banks	58.6218	152.3440
Perl I	59.1121	151.6929	Point Bede	59.3119	152.0024
Perry I	60.6979	147.9300	Point Omega	56.5602	154.3938
Perryville	55.8833	159.1667	Point Pogibshi	59.4287	151.8759

Place Name	Latitude	Longitude	Place Name	Latitude	Longitude
Pete s Pass	59.6500	149.6500	Points Bank	58.6218	152.3440
Peterson B	59.5833	151.3000	Points Banks	58.6218	152.3440
Peterson Spit	59.4883	151.5833	Pony C	59.7500	149.5500
Petes Pass	59.6500	149.6500	Porcupine C	59.7785	149.5873
Petrof Beach	59.2883	150.7550	Port Adam	59.2584	151.9865
Petrof Glacier Beach	59.3588	150.8229	Port Bailey	57.9339	153.0449
Port Chatham	59.2040	151.7934	Port Bainbridge	60.0153	148.3447
Port Dick	59.2347	151.0664	Port Chalmers	60.2492	147.2000
Port Dick Creek	59.3098	151.3132	Pyes	59.4129	150.3957
Port Graham	59.3612	151.8469	Quartz B	59.5192	150.5377
Port Lawrence	58.4982	152.6094	Quicksand C	59.7833	149.7666
Port Lion	57.8682	152.8816	RED RIVER	57.2667	154.6250
Port Nellie Juan	60.5544	148.2400	ROSLYN CREEK	57.6181	152.3083
Port Wakefield	57.8691	152.8545	Rabbit C	59.3716	150.4166
Port William	58.4963	152.5850	Rabbit I	59.3697	150.4003
Portage B	56.9338	153.9326	Rabbit I	59.3716	150.4166
Portage Bay (AP)	57.5380	156.0086	Ragged I	59.4366	150.3761
Posliedni Pt	58.0549	152.7482	Rasberry	58.1194	153.3406
Posliedni Pt	58.4341	152.3271	Rasberry Strait	58.0781	153.0785
Prince of Wales Pass	60.1463	148.0100	Raspberry Cape	58.0576	153.4298
Prot Graham	59.3612	151.8469	Raspberry I	58.0516	153.1372
Pt Adam	59.2584	151.9865	Raspberry I (NW)	58.1194	153.3406
Pt Countess	60.2160	148.0900	Raspberry Strait	58.0781	153.0785
Pt Eleanor	60.5806	147.5600	Red Fox B	58.4634	152.6087
Pt Helen	60.1515	147.7700	Redfox B	58.4634	152.6087

Place Name	Latitude	Longitude	Place Name	Latitude	Longitude
Pt Nowell	60.4381	147.9300	Red River	57.2000	154.6833
Pt Pogibshi	59.4287	151.8759	Renard I	59.9166	149.3333
Pt Steele	60.3500	146.2000	Renard I	59.9229	149.3486
Puale B	57.7397	155.5639	Resfault	60.0040	149.1861
Puffin Cliff B	59.7216	149.6000	Ressurection B	59.8956	149.4318
Puget B	59.9708	148.5289	Ressurrect	60.1101	149.3805
Pye I	59.4129	150.3957	Resurrect	60.1101	149.3805
Rocky Pt	57.6699	154.2001	Resurrection B	59.8956	49.4318
Rocky Pt	57.6707	154.2009	Rocky B	59.2378	151.3876
Rocky R	59.2807	151.4140	Selief B	58.0349	153.0566
Rugged I	59.8641	149.3972	Sentinal Rock	58.6547	152.3427
SALTERY COVE	57.5000	152.7500	Sentinel I	58.6547	152.3427
SEQUAL PT	57.5611	152.2083	Seward	60.1058	149.4396
SEVENMILE BEACH (KOD)	57.6528	154.1417	Sharatin B	57.8564	152.7425
SHAKMANOF C	57.9167	152.6000	Shelikof	58.0833	153.8833
SHAW I	59.0042	153.3833	Shelter B	60.1289	147.9500
SUKOI B	56.9500	154.3500	Sheratin	57.8564	152.7425
Sadie C	59.5111	151.4424	Sheratin B	57.8564	152.7425
San Juan B	59.8046	147.9000	Sheretin B	57.8564	152.7425
Sandy B	59.6500	149.9666	Shuyak Harbor	58.5062	152.6370
Sandy C	59.6500	149.9666	Shuyak I	58.5393	152.5095
Sawmill B	60.0550	148.0050	Shuyak I (E)	58.5368	152.3735
Sawmill B	60.0565	148.0300	Shuyak I (N)	58.6331	152.3711
Sawmill P	60.0550	148.0050	Shuyak I (NE)	58.5754	152.3647
Sea Otter I	58.5209	152.2166	Shuyak I (NW)	58.5792	152.5762

Place Name	Latitude	Longitude	Place Name	Latitude	Longitude
Seal B	58.3983	152.1567	Shuyak I (SE)	58.4834	152.4657
Seal I	58.4440	152.2750	Shuyak I (W)	58.5442	152.6643
Seal I	60.4272	147.4100	Shuyak Strait	58.4801	152.5915
Seal Rocks	59.5167	149.6334	Sitkalidak Strait	57.1999	153.0416
Seiba Pt	57.9536	153.2702	Sitkinak	56.5499	154.1220
Seldovia	59.4252	151.7338	Sitkinak I	56.5499	154.1220
Seldovia B	59.4252	151.7338	Skiff Passage	58.5910	152.5736
Smith I	60.5264	147.3600	Slaughter I	57.3380	156.3323
Snug Harbor	60.2520	147.7300	Sleepy B	60.0697	147.8400
Speidon B	57.6692	153.7328	Suraligo	59.7332	149.9321
Sphinx I	60.4964	147.5800	Surprise B	59.4938	150.4949
Spiridon	57.6692	153.7328	Swikshak B	58.6032	153.8420
Spiridon B	57.6692	153.7328	Swikshak Lagoon	58.6200	153.7503
Spruce Cape	57.8286	152.3206	TANGINAK	57.1750	153.0250
Spruce I	57.9206	152.4327	TRIP C	57.9583	152.4583
Spruce I (East Cape)	57.9240	152.3241	TWOCONE PT	57.8333	153.8917
Spruce I (N)	57.9616	152.4783	Table MT	58.9391	152.1675
Spruce I (NE)	57.9672	152.4146	Takli	58.0604	154.4948
Spruce I (North Cape)	57.9759	152.4257	Takli I	58.0604	154.4948
Spruce I (SE)	57.9047	152.3357	Tanaak Cape	58.1273	153.2034
Squire I	60.2482	147.9300	Tanner Head	56.8663	154.2462
Squirrel B	60.0039	148.1400	Taroka Arm	59.6154	150.1434
Squirrel I	60.3331	147.9000	Taroka Head	59.6106	150.1172
St. Hermans Harbor (B)	57.7778	152.4125	Tatitlek Village	60.8614	146.6700
St. Paul Harbor	57.7659	152.4425	Terrace I	57.3819	156.2738

Place Name	Latitude	Longitude	Place Name	Latitude	Longitude
Stariski	59.8833	151.8000	Tetrakof	58.5208	152.4022
Stariski Cr	59.8833	151.8000	Tetrakof Pt	58.5208	152.4022
Stockdale Harbor	60.3117	147.2000	Three Hole B	59.7756	149.6307
Storey I	60.7278	147.4300	Three Saints B	57.1238	153.4908
Sturgeon Head	57.5171	154.6140	Thumb B	60.2075	147.8200
Sturgeon R	57.5328	154.5126	Thunder B	59.5636	150.1914
Sud I	58.8953	152.2171	Tolstoi Pt	58.4001	152.1305
Sunny C	57.9007	152.4259	Tonki B	58.3834	152.0166
Tonki B (NE)	58.3650	152.0500	Tonki B (N)	58.3450	152.0101
Tonki B (Outer)	58.3834	152.0166	Veikoda B	57.9280	153.2828
Tonki Cape	58.3544	151.9857	Verdant C	59.7166	149.7333
Tonsina B	59.3084	150.9214	Verdant I	59.7166	149.7333
Tugidak	56.5038	154.6245	Vickoda B	57.9280	153.2828
Tugidak I	56.5038	154.6245	Viekoda B	57.9280	153.2828
Tugidak I (W)	56.4271	154.7719	Village I	57.7897	153.5532
Tugidak Lagoon	56.5777	154.5006	Village Pt	57.7897	153.5532
Tugidak Passage	56.5716	154.3753	West Amatuli	58.9333	152.0500
Tugidnak	56.5038	154.6245	West Amatuli I	58.9313	152.0567
Tutka B	59.4772	151.4563	Western Inlet	58.5953	152.6187
Twin B	59.9568	148.2200	Whale B	60.2241	148.1800
Two Arm B	59.6172	150.0881	Whale I	57.9542	152.7898
Ugak B	57.4534	152.6998	Whale Passage	57.9340	152.8389
Ugak I	57.3806	152.2858	Whibey B	59.9593	148.9570
Uganik	57.8400	153.5322	Whiby B	59.9593	148.9570
Uganik B	57.8272	153.5274	Whidbey B	59.9593	148.9570

Place Name	Latitude	Longitude	Place Name	Latitude	Longitude
Uganik B	57.8400	153.5322	Wide B	57.3385	156.4352
Uganik I	57.8906	153.3699	Widlay B	59.9593	148.9570
Upper Passage	60.5381	147.6300	Wildcat C	59.4232	150.3714
Ushagat I	58.9245	152.2759	Wildcat P	59.3804	150.4018
Ushaget	58.9245	152.2759	Windy B	59.2232	151.5127
Uyak	57.6379	154.0040	Yalik B	59.4607	150.6112
Uyak B	57.5850	153.9020	Vantage Rock	58.4089	152.1749
Windy Pt	59.2216	151.4550	Womans B	57.7128	152.5364
Yalik Beach	59.4254	150.7203	Yalik Glacier Beach	59.4254	150.7203
Womens B	57.7128	152.5364	Yalik Pt	59.4438	150.5806
Wooded I	57.9608	152.4994	Yantarni B	56.8202	157.1307
Wooded I	59.8709	147.4000	Yukon I	59.5250	151.5000
Woody I	57.7859	152.3348	Zachar B	57.5529	153.7710
Wonder B	58.6130	152.5897	Zacher B	57.5529	153.7710
Yalharring	59.5937	150.5363	Zaimka I	57.7314	152.4676

APPENDIX B:
SHORELINE TYPES IN
BIRD COLLECTION AREAS

The following tables give detailed information for each 15-minute block of coastline in the searched areas of Prince William Sound, Kenai Fjords, Lower Cook Inlet, Barren Islands, Katmai National Park, Becharof National Wildlife Refuge, Aniakchak National Monument, Kodiak Island, and the Alaska Peninsula, including the Semidi Islands. For each 15-minute block in each area, the tables provide the following information: the linear distance (in kilometers) of each shoreline type (as defined by the Environmental Sensitivity Index Classification), the total linear distance of each 15-minute block, the total linear distance of each shoreline type, and the proportion of the total coastline distance represented by each shoreline type.

Table B-1. Summary of Linear Coastal Distances (km) by Shoreline Type, Prince William Sound (West)
(From Environmental Sensitivity Index Classification)

Cell Name	Fine/ Medium Sand Beach	Coarse Sand Beach	Mixed Sand/ Gravel Beach	Gravel Beach	Exposed Rocky Shore	Exposed Wave-Cut Platform	Sheltered Rocky Shore	Exposed Tidal Flat	Sheltered Tidal Flat	Marsh	Ice	Un-clas-sified	Total
A-46	0.00	0.00	11.28	24.80	0.00	0.00	15.68	0.00	3.11	5.51	0.00	0.00	60.37
A-47	0.00	0.00	42.06	27.19	14.52	0.09	26.56	0.00	10.21	8.68	1.72	4.94	135.97
A-48	0.00	0.00	33.03	17.05	24.40	0.35	32.67	0.00	2.22	7.87	0.00	1.72	119.29
A-49	0.00	0.00	58.71	24.32	13.61	0.00	50.49	0.00	6.52	5.59	0.00	9.74	168.98
A-50	0.00	0.00	102.84	7.24	18.86	0.00	75.14	0.00	3.42	4.29	0.00	3.22	215.01
A-51	0.00	0.00	55.50	20.97	17.60	0.00	64.45	0.00	3.37	1.08	0.00	5.12	168.10
A-52	0.00	0.00	84.52	12.62	19.80	0.00	22.10	0.00	7.10	0.00	4.04	5.00	155.18
A-53	0.00	0.00	28.23	0.00	13.53	14.08	11.76	0.00	3.19	0.00	0.00	1.77	72.57
B-46	0.00	1.84	18.37	4.03	0.00	0.00	44.36	0.00	4.13	4.00	0.00	0.54	77.26
B-47	0.66	0.00	28.09	13.11	2.77	0.00	92.79	0.00	8.83	5.75	0.00	2.53	154.52
B-48	0.00	2.96	49.51	30.54	16.80	3.19	95.69	0.00	7.59	5.08	0.00	1.33	212.71
B-49	0.00	0.00	26.33	34.71	15.28	1.34	13.48	0.00	3.60	0.09	0.00	1.08	95.92
B-50	0.09	0.00	13.18	3.93	27.22	4.68	22.40	0.00	0.00	0.00	0.00	0.00	71.50
B-51	4.92	0.00	39.67	23.80	29.51	16.97	4.56	0.00	0.00	0.00	0.00	0.89	120.34
B-52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C-46	0.00	0.00	0.47	2.13	0.00	0.00	11.58	0.00	5.36	10.63	0.00	8.38	38.55
C-47	0.00	0.00	17.77	7.89	0.38	0.00	32.42	0.00	4.81	2.99	11.13	1.30	78.70
C-48	0.00	0.00	76.09	41.12	19.13	0.97	78.27	0.00	9.76	4.14	0.00	8.99	238.47
C-49	0.00	0.00	52.03	22.72	32.75	18.77	112.21	0.00	1.47	1.95	0.00	2.80	244.69
C-50	0.03	0.00	42.76	10.53	24.75	2.79	65.11	0.00	0.00	0.33	0.00	4.53	150.84
C-51	0.00	0.00	15.67	16.67	0.78	8.51	0.22	0.00	0.19	0.17	0.00	4.76	46.96
C-52	0.00	0.00	8.61	50.87	0.00	25.28	0.00	0.00	12.57	3.96	0.00	0.60	101.89
C-53	0.00	0.00	0.00	2.15	0.00	12.67	0.00	0.00	0.00	0.00	0.00	0.00	14.82
D-47	0.79	0.00	28.98	20.37	31.17	0.67	41.88	0.00	1.98	7.19	5.38	1.88	140.29
D-48	0.47	0.74	40.26	61.40	39.87	0.31	104.59	0.00	5.75	4.78	0.00	0.19	258.36
D-49	0.00	0.00	30.24	41.05	17.61	12.62	51.26	0.00	4.48	0.00	0.00	0.65	157.91
D-50	0.00	0.00	5.47	12.49	0.42	11.82	0.45	0.00	0.00	0.00	0.00	0.58	31.23
D-51	3.42	0.00	5.28	26.35	0.00	24.87	0.00	0.00	6.30	0.38	0.00	7.69	74.29
D-52	0.00	0.00	0.00	3.07	0.00	23.59	0.00	0.00	5.12	0.00	0.00	0.00	31.79

Table B-1. Summary of Linear Coastal Distances (km) by Shoreline Type, Prince William Sound (West) (From Environmental Sensitivity Index Classification) (Continued)

Cell Name	Fine/ Medium Sand Beach	Coarse Sand Beach	Mixed Sand/ Gravel Beach	Gravel Beach	Exposed Rocky Shore	Exposed Wave-Cut Platform	Sheltered Rocky Shore	Exposed Tidal Flat	Sheltered Tidal Flat	Marsh	Ice	Un-clas-sified	Total
D-53	0.00	0.00	0.00	0.00	0.00	2.80	0.00	0.00	0.00	0.00	0.00	0.00	2.80
E-48	0.00	0.00	8.72	29.26	21.87	5.75	5.65	0.00	1.13	0.00	0.00	0.00	72.39
E-49	7.08	0.00	4.19	12.22	0.00	35.48	0.51	0.12	0.79	0.00	0.00	0.00	60.40
E-50	6.55	0.00	1.02	8.34	3.16	17.81	0.00	2.52	0.00	0.00	0.00	5.38	44.76
E-51	2.44	0.00	3.97	6.69	3.52	31.12	0.00	0.00	0.00	0.00	0.00	3.77	51.50
Total	26.45	5.54	32.85	619.60	409.30	276.50	1076.3	2.64	123.00	84.46	22.27	89.38	3668.36
Proportion	0.01	0.00	0.25	0.17	0.11	0.08	0.29	0.00	0.03	0.02	0.01	0.02	

Table B-2. Summary of Linear Coastal Distances (km) by Shoreline Type, Kenai Fjords
(From Environmental Sensitivity Index Classification)

Cell Name	Fine/ Medium Sand Beach	Coarse Sand Beach	Mixed Sand/ Gravel Beach	Gravel Beach	Exposed Rocky Shore	Exposed Wave-Cut Platform	Sheltered Rocky Shore	Exposed Tidal Flat	Sheltered Tidal Flat	Marsh	Ice	Un-clas-sified	Total
D-43	0.00	0.00	24.22	0.00	12.92	0.00	0.49	11.20	0.00	5.80	0.00	0.00	54.63
D-44	0.00	0.00	6.54	3.00	1.68	0.00	17.75	0.00	0.00	1.73	0.00	0.00	30.71
D-46	0.00	0.00	0.41	5.17	3.19	0.00	1.61	0.00	0.86	0.00	0.00	0.00	11.25
E-40	0.00	0.00	0.00	0.00	0.00	0.00	13.54	0.00	0.00	0.00	0.00	0.00	13.54
E-41	0.00	0.00	14.43	1.38	8.68	0.00	21.10	2.10	0.00	0.00	1.84	4.14	53.68
E-42	0.00	0.00	50.69	0.64	54.96	0.00	42.52	0.00	0.00	0.00	1.81	39.56	190.19
E-43	0.00	2.09	9.07	3.77	62.70	0.00	16.23	0.00	0.00	0.00	0.00	2.85	96.71
E-44	0.00	0.00	6.50	5.97	18.60	0.00	8.28	0.00	0.00	0.00	0.00	4.98	44.32
E-45	0.00	0.00	11.27	1.92	11.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	24.80
E-46	0.00	0.00	3.19	3.38	17.36	0.00	0.00	0.00	1.15	3.67	0.00	0.00	28.75
E-47	0.00	0.00	1.93	4.38	10.99	0.00	0.27	0.00	0.00	0.00	0.00	8.58	26.15
F-38	0.00	0.00	9.94	0.74	1.37	0.00	38.33	8.44	0.00	1.13	0.00	1.96	61.91
F-39	0.00	0.00	26.23	0.91	8.35	0.00	59.25	2.76	0.00	3.55	0.00	19.04	120.10
F-40	0.00	0.00	18.14	0.90	38.19	0.00	35.31	2.01	0.00	0.00	3.03	10.85	108.44
F-41	0.00	0.00	24.45	1.74	46.88	0.00	36.15	5.80	1.73	2.20	0.00	3.02	121.97
F-42	0.00	0.00	2.65	0.55	106.14	0.00	10.64	0.00	0.00	0.00	0.00	10.47	130.44
F-43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.29
G-35B	0.00	0.00	1.80	0.00	1.82	0.00	25.29	0.00	6.98	3.99	0.00	3.53	39.88
G-36	0.00	0.00	8.55	0.87	6.37	0.00	36.44	0.00	3.26	6.72	0.00	6.92	69.12
G-37	0.00	1.32	11.50	3.89	28.19	0.00	19.88	0.00	1.17	1.75	0.00	19.24	86.94
G-38	0.00	1.73	5.29	5.55	47.62	0.00	71.64	3.74	2.29	0.50	0.00	24.82	163.19
G-39	0.00	0.00	0.52	0.00	99.26	0.00	54.00	0.00	0.00	0.00	0.00	4.57	158.35
G-40	0.00	0.00	0.00	0.00	2.31	0.00	0.00	0.00	0.00	0.00	0.00	0.19	2.51
H-33	0.00	1.55	18.87	0.00	5.62	23.45	13.40	1.16	6.38	0.00	0.00	16.85	87.27
H-34	0.00	0.00	18.89	0.00	19.59	14.76	18.30	0.00	6.19	8.06	0.00	17.50	103.29

Table B-2. Summary of Linear Coastal Distances (km) by Shoreline Type, Kenai Fjords (From Environmental Sensitivity Index Classification) (Continued)

Cell Name	Fine/ Medium Sand Beach	Coarse Sand Beach	Mixed Sand/ Gravel Beach	Gravel Beach	Exposed Rocky Shore	Exposed Wave-Cut Platform	Sheltered Rocky Shore	Exposed Tidal Flat	Sheltered Tidal Flat	Marsh	Ice	Un-clas-sified	Total
H-35	0.00	0.00	6.65	0.00	23.71	21.43	13.28	0.00	0.00	0.00	0.00	24.23	89.30
H-36	0.00	0.00	6.66	1.62	18.03	3.95	6.71	0.00	0.00	0.00	0.00	10.40	47.37
H-37	0.00	2.92	0.29	0.00	19.49	0.00	0.00	0.00	0.00	0.00	0.00	0.43	23.13
Total	0.00	9.61	288.7	46.38	675.64	63.59	560.4	37.21	30.01	39.1	6.68	234.40	1991.76
Proportion	0.00	0.00	0.14	0.02	0.34	0.03	0.28	0.02	0.02	0.02	0.00	0.12	

Table B-3. Summary of Linear Coastal Distances (km) by Shoreline Type, Lower Cook Inlet
(From Environmental Sensitivity Index Classification)

Cell Name	Fine/ Medium Sand Beach	Coarse Sand Beach	Mixed Sand/ Gravel Beach	Gravel Beach	Exposed Rocky Shore	Exposed Wave-Cut Platform	Sheltered Rocky Shore	Exposed Tidal Flat	Sheltered Tidal Flat	Marsh	Ice	Un-clas-sified	Total
D-34	0.00	0.00	21.50	0.00	0.00	0.00	0.00	8.52	0.00	0.36	0.00	1.65	32.03
D-35	0.00	0.00	11.98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.98
E-27	0.00	0.00	0.00	0.00	0.00	0.00	7.04	0.00	9.27	30.68	0.00	0.00	46.98
E-28	13.76	5.39	14.97	2.01	0.00	3.33	0.00	13.78	0.00	18.47	0.00	0.00	71.71
E-29	0.00	0.00	10.29	12.71	0.31	2.19	0.00	8.42	0.00	12.52	0.00	0.61	47.05
E-30	0.00	0.00	13.71	0.00	0.00	0.00	0.00	8.42	0.00	23.34	0.00	0.00	45.47
E-33	0.00	0.00	25.81	0.00	0.00	0.00	0.00	9.26	0.00	3.58	0.00	0.00	38.64
E-34	0.00	0.00	8.74	0.00	0.00	0.00	0.00	0.95	0.00	0.00	0.00	0.00	9.70
E-36	0.00	0.00	10.72	0.00	0.00	0.00	0.00	12.89	4.53	3.73	0.00	0.00	31.87
E-37	0.00	0.00	0.84	0.00	0.00	0.00	0.00	0.00	1.31	27.52	0.00	0.00	29.67
F-25	0.00	2.27	2.08	0.83	0.00	1.11	5.41	0.00	7.95	11.54	0.00	0.00	31.19
F-26	0.00	0.00	18.10	3.04	1.27	21.83	23.02	0.00	15.99	4.85	0.00	5.05	93.15
F-27	0.00	0.00	17.47	1.93	1.95	15.24	21.84	0.00	18.00	3.34	0.00	7.05	86.82
F-28	1.19	0.00	0.00	5.69	3.45	13.36	0.00	0.00	0.00	0.50	0.00	0.00	24.19
F-33	0.00	0.00	9.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.07
F-34	0.00	0.00	20.06	0.00	2.32	1.42	0.00	7.89	1.04	3.37	0.00	0.81	36.91
F-35	0.00	0.00	62.63	0.00	8.47	3.11	29.87	36.54	9.57	12.46	0.00	13.01	175.67
F-36	0.00	0.00	32.77	0.00	2.60	0.00	43.55	17.36	3.64	8.29	0.00	4.96	113.18
G-24	0.60	1.38	17.58	1.80	0.00	7.19	11.88	6.68	12.66	3.21	0.00	3.54	66.51
G-25	0.00	0.00	7.52	1.58	0.00	21.16	3.98	3.13	1.12	0.00	0.00	1.87	40.35
G-26	8.63	0.00	0.00	3.81	0.84	20.99	8.77	0.00	1.96	6.11	0.00	0.68	51.79
G-27	0.00	0.00	0.00	0.00	0.00	28.04	2.29	0.00	0.00	0.00	0.00	8.65	38.98
G-33	0.00	0.00	25.05	2.13	6.62	32.07	11.57	2.92	4.42	5.27	0.00	10.83	100.89
G-34	0.00	0.00	25.41	0.00	6.82	6.22	35.15	2.79	2.28	0.00	0.00	4.23	82.90
G-35A	0.00	0.00	14.47	0.00	8.48	0.00	41.36	1.99	0.88	3.84	0.00	3.81	71.02
H-23	0.00	0.00	0.00	0.00	0.00	0.00	4.60	0.00	0.00	3.75	0.00	0.00	8.35
H-24	0.00	0.00	10.11	0.00	1.07	43.71	30.06	14.29	36.27	13.46	0.00	4.84	153.81

Table B-3. Summary of Linear Coastal Distances (km) by Shoreline Type, Lower Cook Inlet (From Environmental Sensitivity Index Classification) (Continued)

Cell Name	Fine/ Medium Sand Beach	Coarse Sand Beach	Mixed Sand/ Gravel Beach	Gravel Beach	Exposed Rocky Shore	Exposed Wave-Cut Platform	Sheltered Rocky Shore	Exposed Tidal Flat	Sheltered Tidal Flat	Marsh	Ice	Un-clas-sified	Total
H-25	0.00	0.00	12.35	0.00	0.00	38.09	4.13	13.48	0.00	5.82	0.00	0.00	73.86
H-26	0.00	8.51	14.79	0.00	0.00	3.67	3.20	19.63	0.00	0.01	0.00	0.00	49.80
H-27	0.00	0.00	0.00	0.00	0.00	5.28	0.00	0.00	0.00	0.00	0.00	0.00	5.28
I-26	0.00	0.00	11.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.23
I-27A	0.00	0.00	11.29	0.00	0.00	17.63	0.99	0.00	0.05	0.00	0.00	3.62	29.96
Total	24.18	17.55	430.5	35.53	44.2	285.6	288.7	188.9	130.9	206.0	0.00	75.21	1727.44
Proportion	0.01	0.01	0.25	0.02	0.03	0.17	0.17	0.11	0.08	0.12	0.00	0.04	

Table B-4. Summary of Linear Coastal Distances (km) by Shoreline Type, Barren Islands (From Environmental Sensitivity Index Classification)

Cell Name	Fine/ Medium Sand Beach	Coarse Sand Beach	Mixed Sand/ Gravel Beach	Gravel Beach	Exposed Rocky Shore	Exposed Wave-Cut Platform	Sheltered Rocky Shore	Exposed Tidal Flat	Sheltered Tidal Flat	Marsh	Ice	Un-clas-sified	Total
1-31	0.00	0.00	9.23	0.99	13.90	3.90	0.00	0.00	0.00	0.00	0.00	5.91	33.93
1-32	0.00	0.00	10.29	1.07	43.78	3.97	0.89	0.00	0.00	0.00	0.00	8.32	68.33
1-33	0.00	0.00	0.00	0.00	6.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.70
Total	0.00	0.00	19.52	2.06	64.38	7.87	0.89	0.00	0.00	0.00	0.00	14.23	108.96
Proportion	0.00	0.00	0.18	0.02	0.59	0.07	0.01	0.00	0.00	0.00	0.00	0.13	

Table B-5. Summary of Linear Coastal Distances (km) by Shoreline Type, Katmai National Park
(From Environmental Sensitivity Index Classification)

Cell Name	Fine/ Medium Sand Beach	Coarse Sand Beach	Mixed Sand/ Gravel Beach	Gravel Beach	Exposed Rocky Shore	Exposed Wave-Cut Platform	Sheltered Rocky Shore	Exposed Tidal Flat	Sheltered Tidal Flat	Marsh	Ice	Un-clas-sified	Total
I-27B	0.00	0.00	19.13	0.00	0.00	12.46	1.93	2.33	6.50	0.00	0.00	3.08	42.35
I-28	0.00	0.00	0.00	0.00	0.00	0.61	0.00	0.00	0.00	0.00	0.00	1.63	2.24
J-25	0.00	0.00	18.58	0.00	1.23	7.02	0.00	15.18	6.49	0.70	0.00	0.32	49.52
J-26	0.00	0.00	29.08	0.00	3.39	3.72	0.00	5.71	2.80	0.00	0.00	5.38	50.07
J-27	0.00	0.00	5.29	1.86	1.87	0.50	0.00	4.06	2.66	0.85	0.00	0.44	17.53
K-23	0.00	0.00	17.93	0.00	0.00	0.00	11.88	0.00	27.04	8.50	0.00	0.02	65.37
K-24	0.00	0.00	50.75	0.38	17.82	29.40	16.80	16.71	13.47	10.29	0.00	12.29	167.91
K-25	0.00	0.00	6.76	1.84	4.18	10.60	0.00	0.00	0.00	0.00	0.00	0.39	23.77
L-20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	5.99	0.00	0.00	0.00	6.13
L-21	0.00	11.49	1.59	0.00	1.83	8.56	0.00	10.30	13.90	5.15	0.00	0.27	53.10
L-22	0.00	1.52	27.31	0.64	5.96	10.80	30.76	13.78	10.97	3.89	0.00	3.41	109.04
L-23	0.00	4.47	51.28	2.32	23.32	8.06	37.34	4.46	17.47	3.97	0.00	6.60	159.31
L-24	0.00	0.00	10.04	0.00	7.64	10.50	0.39	0.00	1.85	0.00	0.00	4.16	34.57
M-21	0.00	0.00	0.00	0.00	0.00	0.21	0.00	0.05	0.00	0.00	0.00	0.00	0.25
Total	0.00	17.48	237.7	7.04	67.24	102.4	99.1	72.72	109.1	33.35	0.00	37.99	784.24
Proportion	0.00	0.02	0.30	0.01	0.09	0.13	0.13	0.09	0.14	0.04	0.00	0.05	

Table B-6. Summary of Linear Coastal Distances (km) by Shoreline Type, Becharof NWR
(From Environmental Sensitivity Index Classification)

Cell Name	Fine/ Medium Sand Beach	Coarse Sand Beach	Mixed Sand/ Gravel Beach	Gravel Beach	Exposed Rocky Shore	Exposed Wave-Cut Platform	Sheltered Rocky Shore	Exposed Tidal Flat	Sheltered Tidal Flat	Marsh	Ice	Un-clas-sified	Total
M-18	0.00	2.84	2.06	0.84	4.72	2.40	0.00	0.00	6.53	0.00	0.00	0.64	20.04
M-19	0.00	0.74	12.45	0.00	1.82	16.71	0.00	4.22	8.48	1.12	0.00	0.20	45.73
M-20	0.00	8.37	12.60	0.00	3.61	20.32	11.11	11.64	9.98	1.24	0.00	7.71	86.58
N-16	0.00	0.00	9.98	1.56	0.00	11.14	0.00	0.00	3.29	0.00	0.00	21.72	47.69
N-17	0.00	1.10	4.06	0.00	6.07	14.61	1.36	0.98	6.30	0.00	0.00	0.00	34.48
N-18	0.00	7.56	5.04	0.00	13.08	12.65	0.00	4.00	1.20	0.00	0.00	0.33	43.87
N-19	0.00	0.00	1.52	0.32	3.64	15.33	0.00	0.00	0.00	0.00	0.00	13.06	33.87
O-14	0.00	0.00	8.85	0.00	0.00	0.00	0.21	0.00	8.73	4.29	0.00	0.00	22.08
O-15	0.00	0.00	42.48	2.72	0.00	30.61	0.22	2.58	19.36	1.80	0.00	13.52	113.30
O-16	0.00	1.18	17.39	2.52	0.00	32.40	0.00	3.16	2.30	0.00	0.00	2.62	61.57
P-13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.83	0.00	0.00	0.00	0.00	8.83
P-14	0.00	0.00	12.75	14.00	9.65	3.88	0.56	7.90	1.23	0.90	0.00	4.89	55.77
P-15	1.46	0.00	34.88	16.95	27.81	26.19	4.87	3.40	3.56	5.48	0.00	21.18	145.76
Q-12	20.72	0.00	5.65	18.02	1.29	25.43	5.06	3.84	0.00	15.44	0.00	0.94	96.38
Q-13	0.00	0.00	12.64	10.89	8.49	32.41	0.00	4.86	4.89	1.58	0.00	9.52	85.28
Q-14	0.00	0.00	1.25	0.00	2.81	8.01	0.00	0.55	0.00	0.00	0.00	13.19	25.82
Q-15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.16
Total	22.18	21.79	183.6	67.82	82.99	252.1	23.39	55.96	75.85	31.85	0.00	109.7	927.22
Proportion	0.02	0.02	0.20	0.07	0.09	0.27	0.03	0.06	0.08	0.03	0.00	0.12	

Table B-7. Summary of Linear Coastal Distances (km) by Shoreline Type, Aniakchak National Monument (From Environmental Sensitivity Index Classification)

Cell Name	Fine/ Medium Sand Beach	Coarse Sand Beach	Mixed Sand/ Gravel Beach	Gravel Beach	Exposed Rocky Shore	Exposed Wave-Cut Platform	Sheltered Rocky Shore	Exposed Tidal Flat	Sheltered Tidal Flat	Marsh	Ice	Un-clas-sified	Total
Q-10	0.00	0.00	3.47	3.56	0.00	0.00	0.88	0.00	0.00	2.71	0.00	7.23	17.84
Q-11	6.48	0.00	7.10	9.30	0.00	23.54	0.02	21.24	0.00	0.20	0.00	3.22	71.09
R-10A	0.00	7.63	5.59	2.17	0.00	4.03	2.17	4.97	0.28	4.29	0.00	1.19	31.13
R-11A	0.00	0.24	4.34	0.00	0.14	12.06	0.00	6.06	0.00	0.00	0.00	3.24	22.84
Total	6.48	7.87	20.50	15.03	0.14	39.63	3.07	32.27	0.28	7.20	0.00	14.88	147.33
Proportion	0.04	0.05	0.14	0.10	0.00	0.27	0.02	0.22	0.00	0.05	0.00	0.10	

Table B-8. Summary of Linear Coastal Distances (km) by Shoreline Type, Kodiak
(From Environmental Sensitivity Index Classification)

Cell Name	Fine/ Medium Sand Beach	Coarse Sand Beach	Mixed Sand/ Gravel Beach	Gravel Beach	Exposed Rocky Shore	Exposed Wave-Cut Platform	Sheltered Rocky Shore	Exposed Tidal Flat	Sheltered Tidal Flat	Marsh	Ice	Un-clas-sified	Total
J-30	0.00	0.00	100.02	11.83	10.74	29.76	8.28	0.00	15.13	5.82	0.00	15.72	197.29
J-31	0.00	0.00	9.45	12.24	16.50	33.61	56.08	0.00	2.17	0.38	0.00	27.57	158.01
J-32	0.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.64	2.64
K-28	0.00	0.00	3.98	4.17	1.73	3.02	0.00	0.00	0.00	0.00	0.00	1.13	14.03
K-29	0.00	0.00	67.76	18.40	35.88	17.82	8.70	1.92	1.64	0.00	0.00	10.27	162.38
K-30	0.00	0.00	61.49	8.55	14.85	25.95	4.81	0.00	1.81	0.00	0.00	11.98	129.45
K-31	0.00	0.00	0.00	29.93	12.23	16.09	116.69	0.00	0.00	0.00	0.00	21.42	196.36
K-32	0.00	0.00	6.97	13.68	0.00	32.99	57.25	0.00	2.34	0.00	0.00	19.13	132.35
K-33	0.00	0.00	0.00	7.42	5.71	16.76	0.00	0.00	0.00	0.00	0.00	10.87	40.76
L-27	0.00	0.00	20.07	8.70	7.58	1.16	0.00	0.00	0.00	0.00	0.00	3.78	41.29
L-28	0.00	0.00	37.93	35.14	25.99	7.84	7.21	0.00	0.52	0.00	0.00	5.05	119.68
L-29	0.00	0.00	18.19	31.66	6.45	1.76	20.72	2.25	5.19	0.00	0.00	7.54	93.76
L-30	0.07	0.00	5.52	10.86	22.29	0.00	43.70	0.00	0.00	0.00	0.00	30.16	112.61
L-31	0.00	0.00	4.95	12.64	22.27	0.00	51.52	0.00	0.00	0.00	0.00	24.80	116.18
L-32	0.00	0.00	3.51	5.39	16.13	0.68	17.80	0.00	0.54	0.00	0.00	2.08	46.13
L-33	0.00	0.00	6.59	9.25	10.25	9.09	0.00	0.00	0.00	0.00	0.00	5.70	40.88
M-25	0.00	0.00	15.31	3.54	11.65	0.00	0.00	0.00	0.00	0.52	0.00	6.65	37.68
M-26	0.00	0.00	26.29	0.36	19.31	4.58	8.92	0.00	4.61	0.00	0.00	7.96	72.03
M-27	0.00	0.00	65.23	1.85	12.93	26.90	21.36	0.00	6.86	3.50	0.00	9.31	147.93
M-28	0.00	0.00	74.19	11.50	11.17	32.06	19.51	0.00	0.64	0.38	0.00	6.26	155.70
M-29	0.00	0.00	0.00	67.48	3.08	38.22	35.52	0.05	0.44	0.00	0.00	3.82	148.60
M-30	0.00	0.00	15.04	12.91	9.21	13.25	40.85	0.00	3.12	2.90	0.00	5.62	102.92
M-31	0.00	0.00	14.35	5.83	2.24	93.79	53.17	0.00	0.00	0.00	0.00	17.41	186.79
M-32	0.00	0.00	0.00	0.00	0.00	4.29	4.31	0.00	0.00	0.00	0.00	2.77	11.37
N-22	0.00	0.00	9.49	0.26	1.17	3.44	0.00	0.00	16.18	0.00	0.00	0.68	31.22
N-23	0.00	0.00	26.17	1.98	1.88	4.43	0.00	0.00	3.27	0.00	0.00	2.31	40.04

Table B-8. Summary of Linear Coastal Distances (km) by Shoreline Type, Kodiak
(From Environmental Sensitivity Index Classification) (Continued)

Cell Name	Fine/ Medium Sand Beach	Coarse Sand Beach	Mixed Sand/ Gravel Beach	Gravel Beach	Exposed Rocky Shore	Exposed Wave-Cut Platform	Sheltered Rocky Shore	Exposed Tidal Flat	Sheltered Tidal Flat	Marsh	Ice	Un-clas-sified	Total
N-24	0.00	0.00	29.14	0.00	1.34	7.96	1.87	0.00	0.00	0.00	0.00	1.95	42.26
N-25	0.00	0.00	2.67	66.07	30.31	13.04	19.25	1.30	5.81	0.40	0.00	20.51	159.37
N-26	0.00	0.00	25.53	12.71	7.87	2.33	27.34	3.48	16.90	1.30	0.00	5.71	103.16
N-27	0.00	0.00	3.01	6.97	0.00	0.00	42.67	0.00	6.89	0.00	0.00	1.75	61.29
N-28	0.00	0.00	3.71	0.00	0.00	0.00	3.52	0.00	6.62	0.00	0.00	0.00	13.84
N-29	1.21	0.00	4.40	24.24	0.00	1.72	0.00	0.00	1.90	3.32	0.00	0.11	36.90
N-30	0.00	2.02	4.95	0.85	0.00	0.00	12.24	0.00	8.86	3.08	0.00	0.44	32.43
N-31	0.00	0.28	0.00	1.04	8.37	30.67	39.11	0.00	0.00	0.00	0.00	10.09	89.56
N-32	0.00	0.00	0.00	0.00	0.78	14.01	7.84	0.00	0.00	0.00	0.00	4.02	26.64
O-21	0.00	0.00	4.95	0.00	12.95	2.85	0.00	0.00	0.00	0.00	0.00	7.74	28.49
O-22	0.00	0.00	34.85	0.83	6.29	10.42	0.00	0.00	9.09	4.76	0.00	1.58	67.83
O-25	0.00	0.00	2.93	50.33	0.00	0.00	26.99	0.00	1.88	0.00	0.00	1.72	83.85
O-26	0.00	0.00	0.00	9.59	0.00	0.00	1.57	0.00	12.90	0.00	0.00	1.13	25.20
O-28	0.00	0.00	21.57	24.71	0.00	4.12	0.00	0.00	3.33	3.62	0.00	1.77	59.12
O-29	0.93	0.00	27.75	33.31	1.06	20.49	2.05	0.00	2.48	1.02	0.00	12.89	101.98
O-30	0.00	0.63	12.64	0.00	0.00	37.84	13.92	0.00	0.00	1.14	0.00	7.80	73.97
O-31	0.00	0.00	0.00	0.00	0.49	25.84	15.58	0.00	0.00	0.00	0.00	1.74	43.65
P-22	0.00	0.00	29.38	0.00	0.34	0.90	0.00	0.00	0.00	0.00	0.00	0.21	30.83
P-23	0.00	0.00	0.00	2.35	0.00	0.00	10.90	0.00	0.00	0.00	0.00	29.16	42.41
P-24	0.00	0.00	5.17	9.83	0.00	0.00	65.07	0.00	2.91	0.00	0.00	3.03	86.01
P-25	0.00	0.00	16.32	0.00	0.00	0.67	53.27	0.00	1.80	5.36	0.00	1.49	78.91
P-26	0.00	0.00	24.84	4.47	10.05	4.90	33.65	0.00	0.00	0.00	0.00	4.90	82.81
P-27	3.30	0.00	75.31	5.67	2.94	31.04	12.26	0.00	8.06	4.28	0.00	[illegible]	150.50
P-28	0.00	0.00	64.16	4.83	0.00	26.55	19.36	5.70	8.92	5.46	0.00	12.09	147.08
P-29	0.00	0.00	9.06	4.74	6.99	8.21	0.00	0.00	0.00	0.00	0.00	4.11	33.12
Q-22	0.00	0.00	0.60	0.00	0.00	1.72	0.00	0.00	0.00	0.00	0.00	0.33	2.64
Q-23	0.00	0.00	30.08	1.51	7.83	0.00	3.66	0.00	37.93	2.07	0.00	6.72	89.78

Table B-8. Summary of Linear Coastal Distances (km) by Shoreline Type, Kodiak (From Environmental Sensitivity Index Classification) (Continued)

Cell Name	Fine/ Medium Sand Beach	Coarse Sand Beach	Mixed Sand/ Gravel Beach	Gravel Beach	Exposed Rocky Shore	Exposed Wave-Cut Platform	Sheltered Rocky Shore	Exposed Tidal Flat	Sheltered Tidal Flat	Marsh	Ice	Un-clas-sified	Total
Q-24	0.00	0.00	52.45	0.00	0.00	28.51	46.81	0.00	0.00	0.00	0.00	22.37	150.13
Q-25	0.00	0.00	52.80	0.00	0.00	16.59	24.70	0.00	0.00	1.60	0.00	4.73	100.43
Q-26	0.00	0.00	12.76	1.85	7.61	31.38	13.19	0.00	0.00	0.00	0.00	15.94	82.74
Q-27	0.00	0.00	0.00	0.00	0.00	3.82	0.00	0.00	0.00	0.00	0.00	0.31	4.13
R-22	0.00	0.00	18.52	0.00	0.00	0.00	0.00	3.82	0.00	0.00	0.00	19.75	42.08
R-23	0.00	0.00	35.22	0.00	0.00	0.00	0.00	43.65	0.00	0.00	0.00	45.39	124.26
R-24	0.00	0.00	49.21	0.89	0.00	15.74	41.98	0.00	1.61	1.68	0.00	5.45	116.56
R-25	0.00	0.00	19.42	0.00	0.00	18.79	0.00	0.00	4.91	0.00	0.00	1.15	44.27
S-21	0.00	0.00	10.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.57
S-22	0.00	0.00	18.71	0.00	0.00	0.00	0.00	3.07	0.00	0.00	0.00	0.00	21.78
S-23	0.00	0.00	0.35	0.00	0.00	0.00	0.00	0.57	0.00	0.00	0.00	0.00	0.91
S-24	0.00	0.00	2.91	1.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.14
Total	5.51	2.93	1298.4	593.6	388.5	777.6	1115.2	65.81	207.3	52.29	0.00	526.34	5033.7
Proportion	0.00	0.00	0.26	0.12	0.08	0.15	0.22	0.01	0.04	0.01	0.00	0.10	

Table B-9. Summary of Linear Coastal Distances (km) by Shoreline Type, Alaska Peninsula (Part), Including the Semidi Islands (From Environmental Sensitivity Index Classification)

Cell Name	Fine/ Medium Sand Beach	Coarse Sand Beach	Mixed Sand/ Gravel Beach	Gravel Beach	Exposed Rocky Shore	Exposed Wave-Cut Platform	Sheltered Rocky Shore	Exposed Tidal Flat	Sheltered Tidal Flat	Marsh	Ice	Un-clas-sified	Total
R-10B	2.65	4.26	0.97	14.62	1.27	25.83	0.00	0.00	0.00	0.00	0.00	4.00	59.26
R-11B	0.00	0.00	2.44	0.00	1.20	8.25	0.00	0.00	0.00	0.00	0.00	1.27	25.72
R-12	0.00	3.20	4.31	0.00	5.58	4.72	0.00	0.00	0.00	0.00	0.00	3.39	47.83
R-13	0.00	0.00	3.21	0.00	0.00	2.88	0.00	0.00	0.00	0.00	0.00	0.24	6.33
R-8	1.34	0.00	3.75	22.29	1.41	3.97	11.92	0.00	4.12	0.11	0.00	0.26	67.02
R-9	0.00	3.75	4.00	12.54	0.27	17.64	3.37	0.00	1.01	0.18	0.00	5.68	72.72
S-10	0.00	0.00	1.32	0.00	8.69	2.45	0.00	0.00	0.00	0.00	0.00	4.72	19.84
S-6	0.00	0.00	2.92	49.63	0.39	0.26	13.42	0.00	11.30	11.91	0.00	0.32	118.76
S-7	0.00	0.03	10.99	16.35	0.47	22.01	3.35	0.00	3.72	13.36	0.00	3.12	111.55
S-8	0.00	0.17	8.23	1.05	3.22	11.94	0.00	0.00	0.00	0.52	0.00	0.46	31.30
S-9	0.00	0.00	6.64	0.00	14.94	6.34	0.00	0.00	0.05	0.00	0.00	6.04	48.58
T-13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	33.52	33.52
T-14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	65.57	65.57
T-5	0.00	3.10	2.62	1.87	0.00	0.49	5.29	0.00	0.00	3.85	0.00	0.00	18.44
T-6	0.00	0.00	37.60	4.94	16.30	4.32	49.03	0.00	0.58	12.20	0.00	8.17	162.41
T-7	0.00	0.00	39.73	3.84	39.48	5.10	52.72	0.00	0.00	3.07	0.00	7.37	162.59
T-8	0.00	0.00	15.95	0.00	5.23	14.68	0.00	0.00	0.00	0.00	0.00	0.91	41.59
U-2	5.68	3.41	5.47	12.43	0.00	7.28	1.58	0.00	2.00	13.61	0.00	2.30	77.27
U-3	3.38	6.11	12.00	2.37	20.43	14.16	4.13	0.00	0.00	4.00	0.00	7.67	105.76
U-4	0.00	16.15	9.35	1.25	20.72	7.16	0.00	0.00	0.00	0.00	0.00	6.27	68.17
U-5	0.00	9.76	5.53	4.93	44.73	1.73	2.04	0.00	0.00	0.00	0.00	5.08	86.75
U-6	0.00	0.00	8.12	1.41	28.28	4.94	0.00	0.00	0.00	2.23	0.00	4.84	57.37
U-7	0.00	0.00	0.00	0.00	5.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.02
U-14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.15	5.15
V-2	4.13	0.00	18.31	4.21	12.68	46.37	0.31	0.00	0.00	5.57	0.00	7.58	112.88
Total	17.18	49.94	203.5	153.7	230.3	212.5	147.2	325.1	22.78	70.61	0.00	183.9	1616.67

Table B-9. Summary of Linear Coastal Distances (km) by Shoreline Type, Alaska Peninsula (Part), Including the Semidi Islands (From Environmental Sensitivity Index Classification) (Continued)

Cell Name	Fine/ Medium Sand Beach	Coarse Sand Beach	Mixed Sand/ Gravel Beach	Gravel Beach	Exposed Rocky Shore	Exposed Wave-Cut Platform	Sheltered Rocky Shore	Exposed Tidal Flat	Sheltered Tidal Flat	Marsh	Ice	Un-clas-sified	Total
Total	17.18	49.94	203.5	153.7	230.3	212.5	147.2	325.1	22.78	70.61	0.00	183.9	1616.67
Proportion	0.01	0.03	0.13	0.10	0.14	0.13	0.09	0.20	0.01	0.04	0.00	0.11	

APPENDIX C:
SOURCES OF INFORMATION ON THE BIRD CARCASS COLLECTION EFFORT

I. SOURCE NOTES FOR SEARCH EFFORT COMPILATION

This section summarizes notes extracted from documentary materials, telephone interviews, and written reports on the beached-bird search and recovery effort. Documentary materials include microfilm reels and some photocopies obtained through the U.S. Fish and Wildlife Service (FWS). The photocopies contain notes and reports made by Government personnel relating to the collection of bird carcasses from tidal rips and beaches. Numbers adjacent to notes from microfilm refer to reel and frame number of the reference.

A. Microfilm and Other Documentary Material

1. DOI 001

001-0497 "All dead, oil-fouled birds and small mammals will be inventoried, photographed, and removed from the beach according to FWS and ARC-Kodiak guidelines. (Draft cleanup guidelines for Katmai and Aniakchak, April 1989.)

001-0512 Log of flight to locate oil, Katmai coast, 4/22/89: oil observed 59° 39′ to 152° 18′, 57° 33′ to 152° 11′, and 58° 20′ to 154° 00′(Kukak Bay).

001-0594 on 3 May (approx.), many (1,000?) dead birds in patches of mousse at Cape Douglas.

001-0892 One thousand dead oiled birds Chiniak Beach on 3 May: "Beaches appearing to have no impact from the air are significantly oiled when seen on ground level" (Judy Alderson, National Park Service (NPS). On 5 May, Kashvik Bay heavily oiled.

001-0905 "The Katmai coastline is heavily impacted with oil" as of 28 through 30 April per Jim Boyd, NPS, 1 May 1989.

001-0912 On 20 April 1989; oil was observed "adjacent" to Katmai National Park with LORAN coordinates given, e.g., 58° 47′ to 153° 19′, and others.

001-1065 Aerial sightings of oil near Cape Douglas on 16 April 1989.

001-1231 Comments on Veco pickup crew on *Pursuit*: they lack motivation because they are working by the hour instead of selling the catch (NPS, anonymous). But the *Pursuit* crew picked up more birds (3000) than any other catcher boat. Also, "(S)ections of the coast which are very rocky do not seem to collect birds in the quantities that sand and gravel beaches do..." Indication of the level of effort: In 9 days, *Pursuit* went from Cape Chiniak south to Missak Bay then north again to Hallo Bay.

001-1448 Oil on Katmai on 18 April. By 25 April, mousse along entire Katmai coast ("1989 Raptor Nest Inventory and Productivity Survey Katmai National Park and Preserve" by Margaret Yurick, King Salmon.) Oiled bird wings observed in eagle nests.

001-1466 Table showing locations of dead seabirds collected (mostly bays), Katmai (ibid.).

001-1492 Table showing oil cleanup activity on Katmai, including number of bags of oiled material and number of dead birds.

2. *DOI 003*

003-0004 Kristi Link, Ranger (Telephone 907-224-3175, tour of duty 15 May to 10 September on Aialik Bay) reported 30 to 200 dead birds in Agnes Cove, KFJNP. The cause of death is unknown. The beach is being steam cleaned.

003-0214 A widespread dieoff of glaucous-winged gulls and kittiwakes occurred August and September 1989 at Kenai Fjord due to lack of food(?). Cleaned beaches on Aialik Bay showed an absence of carcasses (carcasses removed through summer).

003-0539 On 30 August 1989, reports were made of fresh oiling at Aniakchak National Monument of fresh bird kills involving scores of birds that showed no exterior oil.

003-0540 Necropsy of puffin and shearwaters collected at Aniakchak Bay 3 September 1989 showed black tar-like substance mixed in a brown viscous fluid in stomach and intestine.

003-0547 Ibid: "Oil on the beaches of Katmai N.P. was first documented by NPS field personnel near Cape Douglas on April 15. During the week of April 22-28 moderate to strong SE winds combined with prevailing currents in the Shelikof Strait to drive oil southwest."

003-0614 At Katmai Bay on 13 August 1989, "The beach was a real oily mess with pumice masking much of the oil present, yet oily mousse patties > 3′ diameter and bird carcasses and parts were everywhere" (Chris Martin, Biotech, Katmai).

003-0666 Maps showing oil by date at Katmai and Aniakchak—possible value.

003-0848 At Shakun Islets (Katmai)—lots of oil and dead oiled birds were reported on 1 August 1989.

003-0933 A post-oil assessment team reported this evidence: two bags of oiled shearwater carcasses from *M/V Columbia* (catcher boat). 25 August through 5 September 1989.

003-0998 On only 2 of 10 days was weather safe enough to patrol "remote" beaches (Jerry Bronson, Biotech, stationed at Aniakchak for several weeks).

003-1031 Oil arrived at Kaflia Bay on extremely high tides the first week in May (by 5 May). Fresh oil arrived again on 4 June (with more high tides).

003-1070 On Kuliak Bay 19 (15?) May 1989, the oil category was light, tarlike; on 18 June, the oil category moderate.

003-1102 At Katmai Bay by 12 June 1989, oil was on the beach; it came in on high tide in early June.

003-1154 "We do not land on bear beaches" (Heidi Herenden, Katmai National Park).

003-1201 "By April 14 oil was sighted off the coast of Katmai NP and by April 18, tides, currents, and winds combined forces bringing the oil to shore near Cape Douglas" (Heidi Herenden, Katmai National Park, King Salmon, "Katmai National Park Marine Mammal Population Status 1989 after the EVOS") (Hearsay: her surveys were 27 June through 6 September).

003-1234 A cleanup crew was present at Shaw Island and Kiupalik Island on 5 May. (Ibid.)

3. DOI 469

469-0390 The Exxon memo stated the intent to reduce the number of bird rescue boats in Prince William Sound from 19 to 8. (5 June 1989).

469-0409 to 0413 The seabird collection effort per Exxon—the number of boats as of the following dates:

	May 10	June 2(?)	Jul 22	After Jul 22
Prince William Sound	31	20	2	0
Seward	40	26	13	7
Homer	6	4	6	0
Kodiak	18	16	13	8
Total	95	66	34	15

469-0419 Instructions for collecting live and dead birds: "Above all else, safety first." "Avoid dangerous beaches...On rocks or cliffs...Be sure to check all crevasses (sic) that your skiff can get into—sometimes birds...cannot be seen from 10 feet out...The skiff and crew are to land and walk any beaches safely accessible. While skiff is ashore...glass the bluffs and hard to reach areas...." (Exxon or Veco instructions)

469-0425 Instructions: "Mark the area searched on above map and...put this form in a ziplock inside the bag of dead birds or mammals collected, or in the box with the live bird."

469-0451 Helicopters are the "only effective means of providing timely intelligence...from the Alaskan Peninsula." (Ron Hood, Refuge Manager, National Wildlife Refuge AP/Becharof (NWR)) 22 May 1989, helicopters were used to relay information on location of dead birds to catcher boats Frame (0519).

469-0488 On 9 May 1989, "nine oil-fouled bird carcasses were collected, with many more still on the beach." (Alaska Maritime Refuge, AP Unit).

469-0492 "All birds observed were partially decomposed....this area was oiled several days or more in the past" (Portage Bay 9 May 1989). (The team walked only limited rocky stretches.)

469-0496 From the 9 May 1989 survey of Puale Bay, J. Tonkin of Kodiak (NWR?) reported, "Apparently over 600 birds had been picked up before our survey."

469-0523 On 5 May 1989, no oil was found between Cape Kayakliut (near Wide Bay) and Yantarni Bay and along Becharof NWR coast except a few small patches of mousse from Kunmik Island to Sutwik Island, Nakalilok Bay and Long Island, and between Lag and Ugaiashak Island.

469-0529 Oil sightings on 3 May 1989 included a patchy mousse the entire distance from Katmai to Dry Bay. Mousse and oiled birds were observed at Puale Bay and Dry Bay (FWS *M/V Tiglax*, per the Becharof NWR file).

469-0543 An oil sighting was made at Puale Bay, Alinchak Bay, and Wide Bay on 1 May.

469-0548 On 30 April, 522 dead oiled birds were counted at Alinchak Bay (Refuge Manager Becharof NWR).

469-0549 At Alinchak Bay on 30 April 1989, "in a stretch of about 1 mile, he counted 190 dead birds along the high tide line. This is a bare minimum since much sand/gravel has been deposited on top of some birds, and often only a small portion of the bird was visible." Also, he "estimated 15% of birds had been at least partially scavenged" (Becharof Refuge file).

469-0557 Oil was observed at Alinchak Bay on 29 April 1989. (Becharof Refuge File).

469-0599 An early winter survey of Becharof NWR revealed oil/mousse/sheen on refuge beaches in November 1989.

469-0629 The running total of dead birds on NPS lands on the Alaska Peninsula as of 28 August 1989 (Kodiak office file) was—

Katmai	7837
Aniakchak	404

Cleanup activities were reported at the end of August, with reports of sizable numbers of dead birds. The implication was that they were oiled because they were associated with oil cleanup, but check with the Kodiak NPS office.

4. "Homer Chronology" (Anonymous)

30 April: "One of the Exxon-contracted bird rescue boats finds over 600 birds in badly deteriorated condition in the Gore Point area. The crew videotapes the birds and then burns them."

6 April: "All accessible beaches on the Barren Islands are walked and searched for oiled birds."

18 April: "Exxon begins by hiring three boats out of Homer; the maximum number of boats out of Homer will be six large boats and two skiffs."

31 May: "Exxon tries to cut the number of bird boats; Hedrick convinces them the three Homer boats are still needed. Homer is still receiving approximately 70 dead birds and 8 dead otters a week."

22 July: "Exxon...reduces the number of bird rescue boats."

25 August: "RD requests Exxon for continued presence of 2 bird rescue boats."

5. *DOI 042*

042-0017 "No bird boats in area...try *Hail Mary* for bird pickup Have 30 birds" (Beverley J., Kitoi Bay, 27 July 1989).

042-0050 "He's got some rotting birds on board and needs them to be picked up!!!" (Beverley J., 26 July 1989).

042-0056 The *Hungry Raven* reported a sick sea lion, "95 dead, old birds and 1 dead eagle" at Grants Lagoon on 26 July 1989.

042-various (e.g., 0107) In late July, Veco boats were picking up dozens of dead birds still but were also seeing lots of live ones.

042-0191 The *Ruff N Ready* reported at Puale Bay 5 dead birds on 25 July 1989.

042-0193 The *Barb M II* reported "55-100 oiled birds buried under logs and sand blown over them" at Puale Bay on 25 July 1989.

042-0235 A sea turtle (dead) and 68 dead birds were found on 23 July 1989 at Larsen Bay (57° 31 N 154° W).

042-? "Between Izhut and Little Afognak sighted heavy sheen-oiled kelp and lots of birds feeding in the sheen" (Sharron W., 1 July 1989).

6. *DOI 005 (Bird Search and Rescue Skiff Reports)*

005-0726 "Need to contact skipper of *Wilson* for idea of coverage" (Dave Bean, skipper of the *Silver Drift* at Pye Islands, 21 April 1989).

005-1058 *Fantasy Island* at Two Arm Bay (Kenai Fjord National Park) on 8 July 1989: "Started at Surok Pt. and work east shore of Paguna Bay. In the first 1/2 mile saw. . . . Approx. 1/2 way down east shore walked beach saw. . . . 3/4 way down east shore walked beach. . . . Walked beach at head of bay and found one unidentifiable dead bird" (Robert Hill, crew member, searching 12 to 14 km of shoreline).

005-1088 *Fantasy Island* at Bear Cove on 10 July 1989: "walked all accessible beaches. . ." "went over to Holgate Arm. . . walked two beaches south of glacier" (20 km of shoreline searched 9 July, apparently a travel day from Two Arm to Aialik Bay)

005-1216 On 19 July 1989, *Silver Drift* crew worked Two Arm Bay and Paguna Bay, which was apparently last worked 8 July 1989 by *Fantasy Island* (interval of 11 days). (See above).

005-1225 On 20 July 1989, *Fantasy Island* "started day working Quicksand Cove. Walked beaches. . . worked shoreline from Quicksand Cove south through Verdant (?) Cove." (about 15 km of shoreline, BES)

005-1334 "Walked the shoreline of Jewel Island," reported *Fantasy Island* on 31 July 1989.

B. Telephone Conversations (11 to 16 January 1991)

1. *Bud Rice, Kenai Fjords National Park, Seward, 11 January 1991*

Oil was seen at Bear Glacier on 20 April. A Veco bird catcher boat showed up on 10 May. Walkable beaches were estimated at 10 to 20 percent of the Kenai Fjords National Park coast (410 total miles of coastline). Rumors reported that oiled birds showed up at the Seward dump, a guard was posted at the dump to prevent oily waste being dumped there.

2. *Ron Hood, Refuge Manager, Becharof NWR, telephone 246-3339*

The Veco search was "something less than effective." He doubts that rocky beaches were searched. Contact Jay Bellinger, Refuge Manager at Kodiak, zone coordinator, for names of Veco skippers.

3. *Donna Dewhurst, Biologist, Becharof NWR, telephone 246-3339*

The frequency of Veco searches were thought to be once a week at Katmai on assigned beaches (some beaches were not assigned, and were done as time permitted); very little Veco effort was spent on the Becharof NWR coast. She thought that Veco might have searched walkable beaches along 100 miles of the Becharof coast three times during summer and rocky beaches once during summer. Sandy beaches constituted 30 percent of Becharof coast. USFWS had its own people at two camps starting 15 June at Puale Bay (the main camp with two paid workers and several volunteers) and at Oily Creek. The main camp collected dead birds; Oily Creek did other work, with a minor amount of dead bird collection (at the beach near camp). Puale Bay is 75 percent walkable. Both camps combined could cover about 20 miles of coastline using zodiacs, so the coverage and effort were good for 20 miles. Puale Bay was searched every 2 days, the beach near camp was searched sometimes twice per day. They rarely encountered Veco bird collection people. The rest of the AP NWR (150 miles of shoreline) was covered by FWS, who landed at the end of a walkable beach from helicopter and were picked up at the far end of the beach. Perhaps 10 percent of AP coast was covered by FWS personnel. "A big slug" of dead oiled birds (several hundred) came ashore at Perryville in early May. Piatt visited Becharof coast early on (May?) and collected and buried several hundred birds (at Puale Bay?). Oiled birds (6 of 40 dead birds?) were collected along the Becharof coast in 1990.

4. *Jerry Bronson, NPS, now at Yosemite (telephone 209-372-0357)*

Bronson was at Aniakchak for 4 to 5 weeks in 1989. He did not collect dead birds because of bears (he would have had to store them at his cabin until pickup). Collecting dead birds was a Veco task. One Veco crew typically had responsibility to search three bays, with 2 to 3 days work required to search one bay. So the interval between searches was a minimum of 6 days, not counting weather, resupply, and days off. The interval was thus longer (more like 10 days). Birds typically came ashore with storms. Veco boats needed to let seas subside after storms before they could come ashore to search beaches, so an interval of a few days was required for weather reasons, in addition to rotating the schedule between bays. Bears, however, searched beaches immediately after storms; i.e., they were observed more frequently on beaches after storms. Veco "stuck with it" on rocky shorelines, which were hard to search. The ratio of rocky to sandy shorelines is about 50:50. On rocky shorelines, certain parts acted as catchment areas for flotsam, including oiled birds. Scavenging bears and eagles were useful to Bronson in pointing out the location of dead birds hidden between rocks on rocky shorelines.

5. *Kelly Weaverling, Veco bird rescue coordinator in Prince William Sound (telephone 424-5565, Box 895, Cordova, AL 99574)*

Prince William Sound had a full complement of catcher boats = (40 to 45 vessels each with 4 to 5 people) on 5 April. "People who walked the beach were very thorough." All birds on the beach were assumed to be found. Beaches (i.e., shorelines) were walked two to three times per week from April to 15 June. Five percent of the beaches (shoreline) in Prince William Sound were difficult to search. On those, a low percentage of birds would have been found. Equal numbers of birds were found on rocky and sandy beaches.

6. Jay Bellinger, Refuge Manager, Kodiak (telephone 487-2600)

He has 800 miles of shoreline under his jurisdiction as zone coordinator of the Kodiak zone (everything south of but not including Barren Islands). Of 38,000 dead birds collected, 22,000 were in this zone. The search effort varied. He could not give an estimate of number of birds missed. Some Veco boats remained at anchor when they should have been searching for birds: However, they had the incentive to work. Some rocky shorelines were searched from the boat, some by walking. They were slippery if covered with oil. Safety was considered first. Some areas were hard to check. They did find carcasses in boulders. He found a lot of heavily moussed bird carcasses in grassy areas at end of summer during surveys to decide on decommissioning of boats and he found carcasses buried in the sand. As for the time interval, he considered the Veco response to be slow. The fastest response was on the east side of Afognak; oil was discovered on 9 April, and the first birds were collected on 15 April. The response was a lot slower on AP. The morgue was set up at Kodiak by late April. Some birds collected in August and September had spots of oil: it is unlikely that late summer birds were not oiled (referring to Piatt's 1 August cutoff). Some dead birds were put in with oily waste. Someone thought (apparently sometime in July) that they didn't need the old carcasses any more, so they were discarded. Jay tried to get an estimate of numbers but had trouble doing so; he guessed that 2,000 birds were discarded. He thinks there was a significant loss of birds at sea; he observed windrows of feathers on the beach in 1989 but not in 1990. USFWS conducted no debriefing for field workers. Dee Butler, USFWS Anchorage-Realty, had drafted a history of agency involvement in spill, but the draft was never finalized.

7. Dave Nysewander, Alaska Maritime NWR, Homer (235-6546)

He gave the following estimate of the search effort at Barren Islands: 50 to 70 percent of the coast was not searched (too rocky), none of Nord Island was checked, 10 to 20 percent of

East Amatuli was checked, none of Sugarloaf was checked, 30 to 40 percent of Sud Island was checked, 40 percent of West Amatuli was checked.

Ed Bailey, Refuge Biologist, went out to Barrens once per week in April and May. He bagged 1800 birds on one visit and left them on the beach (too many birds to carry out). Ian Jones spent a week on the island in May. A camp was established at end of May for a month. Ed Bailey reported on FWS activities in "Beached bird surveys in the Barren Islands April 6-June 16, 1989." Nysewander was in Prince William Sound during the early days of the spill. He thinks that the search effort was better in the Sound, where the beaches are more sheltered and easier to search, so the Sound was 50 to 70 percent searched. (Note Weaverling's opinion above that the Sound was 95 percent searched.) He released 47 dead oiled birds marked with plastic bands from Naked Island down the east shore to the tip of Knight Island. None were recovered.

8. *Janice Meldrum (907-267-1471), Operations Section Chief for NPS Katmai coast*

She worked in Kodiak, deploying catcher boats. She talked to them each evening. The largest bird pickup effort on Katmai was by Veco; NPS had a very small proportion. Seventy-five percent of the Katmai coast was difficult to walk; only 25 percent allowed reasonable walking.

As for the frequency of search, some difficult areas were searched once per month, some difficult areas not at all. Sandy beaches were searched well and often, i.e., once per week, e.g., Hallo Bay, Katmai Bay, and Cape Douglas were searched once per week. They had the most birds. If a helicopter crew saw birds, they would direct catcher boats to the area, so some extra effort was spent there. Most of this effort pertained to the section of Katmai coast from Cape Douglas to Cape Kubugakli. No effort was directed from Kamishak R to Cape Douglas. What was the distribution of recoveries in this area? Lots of birds came into Hallo Bay when oil first arrived (in the thousands), on the order of 40 to 60 through end of May with winds, per her daily conversations with catcher boats. On 1 June, Veco's emphasis switched to cleanup, and the catcher boats disappeared. Her impression was that many birds coming in to beach had already been scavenged at sea. A huge mass of birds were burned on Afognak. The birds had been collected and bagged, but because of foggy weather and fear of bears, the bags were burned.

9. Jay Wells (907-822-5234) concerning the initial response interval

He was at Katmai and accompanied the Veco catcher boat *Pursuit* for 6 days, on or just before 3 May. It was the second boat out; the first was 1 or 2 May. Oil arrived on about 22 April. He said the birds seemed to have been out there a couple of weeks. Some birds were in an advanced state of decomposition. Oil arrived April 20? The Veco crew received no direction or supervision and had no plan. In the absence of supervision, they depended on NPS. Jay directed the search effort. They keyed in on the southwest corner of bays, where sandy beaches became rocky; these parts of bays seemed to catch the birds in greatest numbers. They walked some rocky beaches but did not see anything. To some extent, they received and responded to reports giving locations of dead birds. Approximately 25 percent of birds had been scavenged. He made the following estimates of losses: 10 percent (wild guess) of birds were buried in sand, 10 percent were carried up to dunes by scavengers, and 30 percent of the searches were hindered by bears (those beaches were skipped and not searched). They ran out of bags for birds so they lost ½ day or more (they placed 5 birds in each bag). Problems with supplies apparently were a common occurrence. The *Pursuit* crew were proud to have picked up 1,500 birds in 3 days. They collected 800 birds in 1 day at Hallo Bay. Birds were thick: 30 to 40 birds in 10 meters. All but 2 to 3 were dead. He noted a virtual absence of live birds. On every tide more birds came in. The number "diminished after a month or so."

C. Reports and Memos

1. Edgar Bailey, "Beached bird surveys in the Barren Islands April 6 - June 16, 1989"

All sandy beaches were walked every 7.5 days (an average of eight visits). Sandy beaches comprised 13 percent or 12 km of approximately 90 km of shoreline. The first oil was confirmed on a 14 April visit to the islands.

2. John Piatt, "Seabird and oil pollution surveys conducted from the MV Tiglax in the NW Gulf of Alaska, 1-7 May, 1989," dated May 15, 1989

Trip from Homer via Barren Islands to Puale Bay, Semidis, Barren Islands again. At Puale Bay on 5 May, 187 birds were collected from patch of mousse 5 x 20 m and were buried (these were later discovered and turned in to the collection center by the Puale Bay field crew). He observed, but did not remove, another 289 birds on the beach. The total number of birds on 2,800 m (about 90 percent) of the main beach east of the river was 580.

3. Nysewander, Memo to Regional Office, 26 April 1989, "Interim trip report concerning surveys associated with the April 5-18 1989 boat and beached bird surveys in Prince William Sound"

"Carcasses of dead birds and mammals disappeared, probably through either scavenging or drifting, and the carcasses picked up represent a very low percentage of what died—perhaps no more than 5 percent, if that even. . . . We collected all dead bird and mammal carcasses. . . . This became difficult as carcasses became scavenged. Often there would only be breast feathers or some other minimal remains left."

In a corpse drift experiment, 47 whole carcasses were banded and released within 200 m of shoreline along 20 nmi of Eleanor and Knight Islands. We intended to release 80 to 90 more carcasses, but because of negative public response, the regional office discontinued the experiment. No recoveries were made: "So far this suggests that the collection effort has not even been able to pick up 5 percent of the dieoff." Estimates of mortality were made by—

- Extrapolation from known densities: 875 km coast was impacted seriously at 22 birds per km (Irons et al., 1985), affecting 19,250 birds. Add open water, 3,990 km^2 covered by oil with a density of 7.5 birds per km^2 (seaducks and alcids)(Dwyer et al.) affecting 29,925 birds for a total of 49,175 birds.

- Extrapolation from avian carcasses recovered: 2,346 returned to Valdez as of the date of the memo: "I have been told that between 5 and 30 percent has been the recovery rate . . . in past spills. All parties agree that conditions surrounding this spill will create a recovery rate closer to 5 percent. If 5 percent is chosen . . . then the total initial avian mortality in the Sound would be estimated at 46,920 birds. This is remarkably similar to the estimate derived. . . ." above.

4. *Dan Stinnett (FWS biologist), "Shoreline cleanup efforts (July 4-26, 1989) Puale Bay, Becharof National Wildlife Refuge"*

90.3 percent of 307 bird carcasses found from 4 to 26 July were oiled externally. He discovered the cache of 170 birds buried by Piatt (Piatt listed 187) in early May and transferred them to bird collectors.

5. *Karen Jettmar, volunteer, The Wilderness Society, memo: "Boat Trip to Kenai Fjords National Park"*

On 27 April 1989, upon leaving Seward, she reported, "It has been raining for a week throughout Prince William Sound and the Gulf of Alaska. Cleanup efforts have been hampered considerably by stormy weather and rough seas. Today was no exception. . . . Don Oldaw (skipper of *M/V Spirit*) said three weeks ago there was thick mousse across Cheval Passage. Also, earlier birds were reportedly found on Bear Glacier beach, one every three feet of beach. . . . The Chiswell Islands and the Pye Islands . . . were hit hard. . . . A report came to us second or third hand from Eric, captain of *M/V Shaman*. He said that 600 birds had been found on one trip out to Gore Point. The boat involved in boat collecting there gathered all the birds together on the beach and burned them."

Oil was observed in Beauty Bay, Quartz Bay, Black Bay, Thunder Bay, and Two Arm Bay, although, as she reported, "There is a noticeable lack of birds in this area," i.e., Taroka Arm of Two Arm Bay. Quite a few black bears were observed in Taroka Arm. From a trip report by Charles Gilbert, NPS (same trip), "From radio reports we learned that the greatest boat activity (collecting birds) is currently in the outer portions of the Pye Islands (Kitten Pass in particular) and the Gore Point area. On April 30, the DEC helicopter crew told Page that one and a half feet of oil is on a Pye Island beach. We heard numerous reports of oiled birds and otters from the Pye Islands."

6. Bud Rice, Trip report 14 through 16 April 1989

In Black Bay, dead oiled birds were wedged between boulders.

Trip report 20 April 1989: On Bear Glacier Beach, oily bird carcasses were found every 15 to 30 m.

II. SOURCE NOTES FOR CARCASS BURIAL

This section summarizes notes on carcass burial. These notes were extracted from documentary materials, telephone interviews, and written reports. Documentary materials include microfilm reels and some photocopies obtained through the U.S. FWS that contain notes and reports made by Government personnel relating to the collection of bird carcasses from tidal rips and beaches. Numbers adjacent to notes from microfilm refer to the reel and frame number of the reference.

A. Microfilm and Other Documentary Material

1. DOI 001

001-0899 "Many of the dead oiled birds have been scavenged; bear and fox tracks go through the oil in the intertidal. . . . Observed again that the oil/oiled wildlife is quickly hidden by clean sand" (Ray Bane, Katmai National Park, helicopter survey 1 May 1989).

001-0901 "Much of the oil is hidden under newly deposited sand. Seemed to (sic) roughly one third fewer dead birds than observed on May 1, 1989, perhaps because the birds are being buried by fresh sand and/or are drifting back out to sea" (Ray Bane, 2 May 1989, referring to Hallo Bay after a helicopter flight along Katmai coast).

001-0905 "The Katmai coastline is heavily impacted with oil" as of 28 through 30 April per Jim Boyd, NPS, 1 May 1989.

001-0906 "Did not see much oil on confirmed oiled beaches, indicating the oil is being covered with sand" (Jim Boyd, NPS, 6 May 1989, Chiniak Bay).

001-0912 On 20 April 1989, Oil was observed "adjacent" to Katmai National Park with LORAN coordinates given, e.g., 58° 47′ to 153° 19′, and others.

001-0920 "Many dead oiled birds at Kukak (Bay) (are) buried under the cobble substrate," (Colleen Matt, AFG, 6 May 1989).

001-0921 "Some oiled birds (are) almost completely covered with relatively clean sand." (Kevin Paulus, 3 May 1989, Kukak Bay).

2. *DOI 469*

469-0549 on Alinchak Bay 30 April 1989, "in a stretch of about 1 mile, he counted 190 dead birds along the high tide line. This is a bare minimum since much sand/gravel has been deposited on top of some birds, and often only a small portion of the bird was visible" (Becharof Refuge file).

B. Telephone Conversations (11 to 16 January 1991)

1. *Bud Rice, Kenai Fjords National Park, Seward, 11 January 1991*

He noted birds being buried by sand and observed dead birds among boulders at Black Bay on 14 April.

2. *Jay Bellinger, Refuge Manager Kodiak (Telephone 487-2600)*

He has 800 miles of shoreline under his jurisdiction as zone coordinator of the Kodiak zone (everything south of but not including Barren Islands). Of 38,000 dead birds collected, 22,000 were in this zone. He found carcasses in boulders, and at the end of summer during surveys to decide on decommissioning of boats he found a lot of heavily moussed bird carcasses in grassy areas. He also found carcasses buried in the sand. In the interval between the arrival of carcasses on the beach and Veco's arrival, carcasses had been buried. Sand (eroded away) uncovered them late in the season; he personally found carcasses uncovered in September.

C. Reports and Memos

1. Edgar Bailey, "Beached bird surveys in the Barren Islands April 6-June 16, 1989"

On 14 April, the first oil was confirmed on visit to islands.

At Ushagat on 3 May, "rising tides and offshore winds removed all but about 30 of 111 oiled birds . . . on the northeast beach . . ." counted 3 days earlier. (Some of these disappearances could be sand burial; see below.)

On 5 May, "new gravel (was) deposited by surf. . . ."

At Ushagat on 21 May, "on the north and west facing beaches many bird carcasses were partially covered by sand and gravel because of heavy surf. . . ."

At Ushagat from 26 May to 16 June, "The remains of many old carcasses buried by gravel deposition reappeared with changing tides and wind directions."

"Birds on a small section (100 m) of beach facing roughly north, south, and west will be left on the beach and marked with colored plastic ribbons to determine how many are removed or buried by scavengers or by rising tides, winds, and surf" (11 May memo on beach surveys in the Barren Islands).

III. SOURCE NOTES FOR SCAVENGING OF CARCASSES

This section summarizes notes extracted from documentary materials, telephone interviews, and written reports on the scavenging of carcasses from the beachface. Documentary materials include microfilm reels and some photocopies obtained through the U.S. FWS and containing notes and reports made by government personnel relating to the collection of bird carcasses from tidal rips and beaches. Numbers adjacent to notes from microfilm refer to reel and frame number of the reference.

A. Microfilm and Other Documentary Material

1. DOI 001

001-0734 One dead bird was found each 16 km. "Carnivores were abundant and intense scavenging occurred along the beaches. We expect that carcasses of birds may last only a few hours given the suspected levels of scavenging." Scavengers observed were bears, wolverine, river otter, fox, ravens, gulls, magpies (uncommon), and eagles. (Note beach scavenging a common search strategy pre-spill.)

001-0899 "Many of the dead oiled birds have been scavenged; bear and fox tracks go through the oil in the intertidal. . . . Observed again that the oil/oiled wildlife is quickly hidden by clean sand" (Ray Bane, Katmai National Park, from a helicopter survey on 1 May 1989.

001-0946 "Much evidence of scavenging on carcasses on high tide and back into sand dunes," (reported Jay Wall, NPS, at Hallo Bay on 3 May 1989).

001-1289 "At the upper end of Swikshak Lagoon, about two and a half miles from the ocean. . . found two scavenged, heavily oiled carcasses" (David Payer, Katmai National Park). He went on to say that carcasses could have appeared there only by being carried by scavenger. Old bear dung and tracks were seen.

001-1337 Evidence (tracks) was seen of foxes dragging oiled carcasses out of "trap" areas (between logs) to scavenge, 24 August to 7 September 1989 (Maggie Yurick, Katmai National Park).

001-1412 This frame contains one of numerous references to oiled bird wings in eagle nests (here Sukoi Bay).

001-1448 Oil was observed on Katmai on 18 April. By 25 April, mousse appeared along the entire Katmai coast ("1989 Raptor Nest Inventory and Productivity Survey Katmai National Park and Preserve" by Margaret Yurick, King Salmon). Oiled bird wings were seen in eagle nests.

001-1655 This frame contains a study of the impact of EVOS on red foxes on Katmai (David Payer, NPS, King Salmon). Although numerous observations of scavenging occurred, he hypothesized that foxes avoided oiled carcasses.

2. *DOI 003*

003-0508 "(Six) dead oiled birds that had all been scavenged were found and turned over to catcher boats by Krunemaker" (Bob Krunemaker (906-337-4491) Katmai, 15 to 26 June).

003-0519 "In the northeast corner of Katmai Bay, a cormorant, gull rookery is located on a cliff above a heavily oiled beach. Many bears walk the beach...feeding on an unusually large number of young which seem to have fallen out of their nests and a number of dead, oiled cormorants which appear to have washed in" 10 to 21 August.

003-0614 On Katmai Bay on 13 August 1989, "The beach was a real oily mess with pumice masking much of the oil present, yet oily mousse patties > 3′ diameter and bird carcasses and parts were everywhere" (Chris Martin, Biotech, Katmai).

003-0994 This frame describes Aniakchak coast beach surveys for oiled birds (walked "beaches"). Over a 5-week period 100 bird carcasses that had been scavenged, many with oiled feathers, were found. The survey team "regularly found scavenged remains of oiled birds at eagle roosts." They removed the remains only to find new oiled carcasses on later visits (one roost near the base camp was visited 20 times). Foxes scavenged beaches. "New oiled carcasses seemed to be washing onto the beaches fairly regularly." Bear cached oiled GWGU in a bank along the beach (Jerry Bronson, Biotech, 907-486-6730(w) or 916-961-5172(h), who was stationed at Aniakchak for several weeks).

003-1154 "We do not land on bear beaches" (Heidi Herenden, Katmai National Park).

3. DOI 469

469-0471 In a shoreline assessment of Dry Bay on 11 May 1989, Max Schwenke, DEC, noted that "24 dead oiled birds were observed on the beach. (Eight) of the oiled birds were collected and later turned over to the FWS. . . . Obvious sign of bear predation on the oiled bird carcasses was documented via photographs and video."

469-0484 "Dead bird count

Puale Bay — 9 collected
Portage Bay — 4 collected
13 counted (not collected)
17 (59 percent scavenged)"
per Ref. Mgr Becharof NWR

469-0549 on Alinchak Bay on 30 April 1989, "in a stretch of about 1 mile, he counted 190 dead birds along the high tide line. This is a bare minimum since much sand/gravel has been deposited on top of some birds, and often only a small portion of the bird was visible." Also, he "estimated 15 percent of birds had been at least partially scavenged" (Becharof Refuge file).

469-0583 Elaine Snyder-Conn and Patrick Scannel, USFWS, Juneau, in a report on a trip to Green and Knight (?) Islands, 13 to 18 April 1989, noted with surprise that most dead oiled birds were in the "woods" and "above the supralittoral zone. . . . Almost all oiled birds collected had been scavenged by gulls or eagles, and frequently only pieces or feather balls (oiled) remained."

B. Telephone Conversations (11 to 16 January 1991)

1. Bud Rice, Kenai Fjords National Park, Seward, 11 January 1991

The black bear population at Kenai Fjords is very high, with a bear "in every little cove"; small home ranges were found by AF&G. He observed an eagle picking a murre off the water.

2. Jerry Bronson, NPS, now at Yosemite (telephone 209-372-0357)

Bronson was at Aniakchak for 4 to 5 weeks in 1989. He did not collect dead birds because of bears (he would have had to store them at his cabin until pickup). Bird collecting was a Veco task. Birds typically came ashore with storms. Veco boats needed to let seas subside after storms before they could come ashore to search beaches, so an interval of a few days occurred between storms and searches for weather reasons, in addition to rotating schedule between bays. Bears, however, searched beaches immediately after storms; i.e., they were observed more frequently on beaches after storms. On rocky shorelines, certain parts acted as catchment areas for flotsam, including oiled birds. Scavenging bears and eagles were useful to Bronson in pointing out the location of dead birds hidden between rocks on rocky shorelines. He also mentioned crabs as an efficient intertidal scavenger in rocky habitats.

Bears cached dead birds in sandy banks. He dug up one such cache and found 10 to 15 birds.

3. Jay Bellinger, Refuge Manager at Kodiak (telephone 487-2600)

He had 800 miles of shoreline under his jurisdiction as zone coordinator of the Kodiak zone (everything south of but not including Barren Islands). Of 38,000 dead birds collected, 22,000 were in this zone. He thinks a significant loss of birds occurred at sea; he observed windrows of feathers on the beach in 1989, but not in 1990.

4. Janice Meldrum (907-267-1471), Operations Section Chief for NPS, Katmai coast

She worked in Kodiak deploying catcher boats and talked to them each evening. Her impression was that many birds coming in to beach had already been scavenged at sea (could be gulls).

5. Jay Wells (907-822-5234)

He estimated the following losses for carcasses: 25 percent of birds had been scavenged, 10 percent were carried up to dunes by scavengers, and 30 percent of searches were hindered by bears (those beaches were skipped, not searched).

C. Reports and Memos

1. Edgar Bailey "Beached bird surveys in the Barren Islands April 6-June 16, 1989"

At Ushagat on 19 April: "There was no evidence of carcasses being removed from beaches by scavengers. . . ." No bird was found away from the beach; foxes were eradicated in 1988. All scavenging was avian (gulls, ravens, eagles). "Birds on a small section (100 m) of beach facing roughly north, south, and west will be left on the beach and marked with colored plastic ribbons to determine how many are removed or buried by scavengers or by rising tides, winds, and surf" (11 May memo on beach surveys in the Barren Islands).

2. *Nysewander, memo to Regional Office, 26 April 1989, "Interim trip report concerning surveys associated with the April 5-18 1989 boat and beached bird surveys in Prince William Sound"* "

Carcasses of dead birds and mammals disappeared, probably through either scavenging or drifting, and the carcasses picked up represent a very low percentage of what died—perhaps no more than 5 percent, if that even. . . . We collected all dead bird and mammal carcasses. . . . This became difficult as carcasses became scavenged. Often there would only be breast feathers or some other minimal remains left."

3. *Karen Jettmar, volunteer, The Wilderness Society, memo on a boat trip to Kenai Fjords National Park*

Quite a few black bears were observed in Taroka Arm.

4. *Bud Rice, trip report (same trip as K. Jettmar, above)*

Lots of river otter tracks were observed at Paguna Arm.

Report on 14-16 April 1989 trip to Black Bay: Dead oiled birds were wedged between boulders.

Report on 20 April 1989 trip to Bear Glacier Beach: Oily bird carcasses were found every 15 to 30 m.

APPENDIX D:
DERIVATION OF THE ESTIMATOR OF THE NUMBER OF CARCASSES BEACHING BETWEEN VISITS OF BIRD COLLECTION PERSONNEL

Presented here is the derivation of the estimator of the number of carcasses beaching between specific visits to a given beach. The assumed conditions for the model are that (1) a given beach is visited on a given date and all carcasses encountered are removed; (2) Day 1 begins when the searching for carcasses stops; (3) each day an unknown number of carcasses come ashore; (4) carcasses on shore may or may not be scavenged at any time; and (5) after a given number of days the beach is again visited and all carcasses encountered are removed.

The following parameters are used in the model:

Cb_i = number of carcasses beached on day i

m = number of days between visits

Cb* = total number of carcasses beached from day 1 to m

Cr = number of carcasses recovered on day m

Ss_j = probability of a carcass surviving j days; $Ss_0 = 1.0$

The following assumptions are made:

1) Cb_i, Cb* and Cr are random variables.
2) m and the Ss_j are constants.
3) all Cb_i, for i = 1 to m, are identically distributed.
4) All carcasses on the beach are encountered and removed during each visit.

This leads to the following simple results and definitions:

$$E(Cb_i) = E(Cb) = \mu_{Cb},\ for\ all\ i$$

$$E(Cb^*) = E(\sum_{i=1}^{m} Cb_i) = \sum_{i=1}^{m} E(Cb_i) = m \cdot \mu_{Cb} = \mu_{Cb^*}$$

$$E(Cr) = \mu_{Cr}$$

The derivations are obtained from the following relationship:

$$Cr = \sum_{i=1}^{m} Ss_{(m-i)} \cdot Cb_{i}.$$

Taking the expectation of both sides we obtain:

$$\mu_{Cr} = \mu_{Cb} \sum_{j=1}^{m-1} Ss_{j}.$$

which is equivalent to:

$$\mu_{Cr} = (\mu_{Cb}/m) \sum_{j=1}^{m-1} Ss_{j}.$$

Rearranging, we obtain the estimator we require:

$$\mu_{Cb}* = m \cdot \mu_{Cr} (\sum_{j=1}^{m-1} Ss_{j})^{-1}$$

The Ss_j's are obtained as described in Section 6.2. The appropriate estimator of μ_{Cr} would be the mean number of carcasses recovered on the given beach after all inter-visit periods of m days. However, in practice there was not a sample of such periods, so we use the particular value of Cr obtained for a given visit. Like the mean, Cr will be an unbiased estimator of μ_{Cr}, although it will have a large standard error.

If the Ss_j's are considered to be random variables, which is probably more realistic, then the estimator does not change as long as the Ss_j's are independent of the Cb_i's. If the assumption that all carcasses are encountered and removed is not true, the number of carcasses missed on sequential visits should have similar expectations. Violation of this assumption will have little effect on the accuracy of our estimate, although the variance would be underestimated.

APPENDIX E:
FITTING THE WEIBULL DISTRIBUTION (HAZARD FUNCTION) TO CARCASS DRIFT DATA

To model the time to sinking of floating carcasses, we used a survivorship function. The function describes the probability that a carcass survives at least to time t. It has this general form:

$$S(t) = 1 - F(t),$$

where F(t) is the cumulative distribution function of the unconditional sinking rate, f(t), namely the probability that a carcass sinks during the interval t to t+Δt:

$$f(t) = \lim_{\Delta t \to 0} [Pr\{t<t'<t+\Delta t\}/\Delta t],$$

where t' is the time of sinking.

Specifically, we used a two-parameter survivorship curve based on the Weibull Distribution:

$$S(t) = e^{-\lambda t^{\gamma}},$$

where λ is a scale parameter, γ is a shape parameter, S(t) is as defined above, and t is the time of sinking. This function was chosen because it has a reputation of fitting survival data well (Gross and Clark, 1975), it is easily linearized, and it did a good job of fitting the carcass survival data.

Data were fit to to the linearized form of the survivorship function, which is obtained by taking the natural log twice:

$$\ln[\ln\{1/S(t)\}] = \ln(\lambda) + \gamma \ln(t)$$

The fit was achieved using standard least-squares fitting techniques (i.e., linear regressing), which gave the estimates $\hat{\lambda}$ and $\hat{\gamma}$. This is achieved by regressing $\ln[\ln\{1/\hat{S}(t)\}]$ on ln(t), where the $\hat{S}(t)$'s were estimated from the proportions of carcasses surviving at time t, and the t's were the estimated times of sinking. Estimated times of sinking were obtained by linear interpolation between the last time the carcass was known to be floating and the first sampling time when it was determined to have sunk. The regression coefficients are related to the parameters as follows: $b_0 = \ln(\hat{\lambda})$, and $b_1 = \hat{\gamma}$. The fit of the Weibull distribution to the data for releases AK5-AK8 is shown in figures E-1 through E-4.

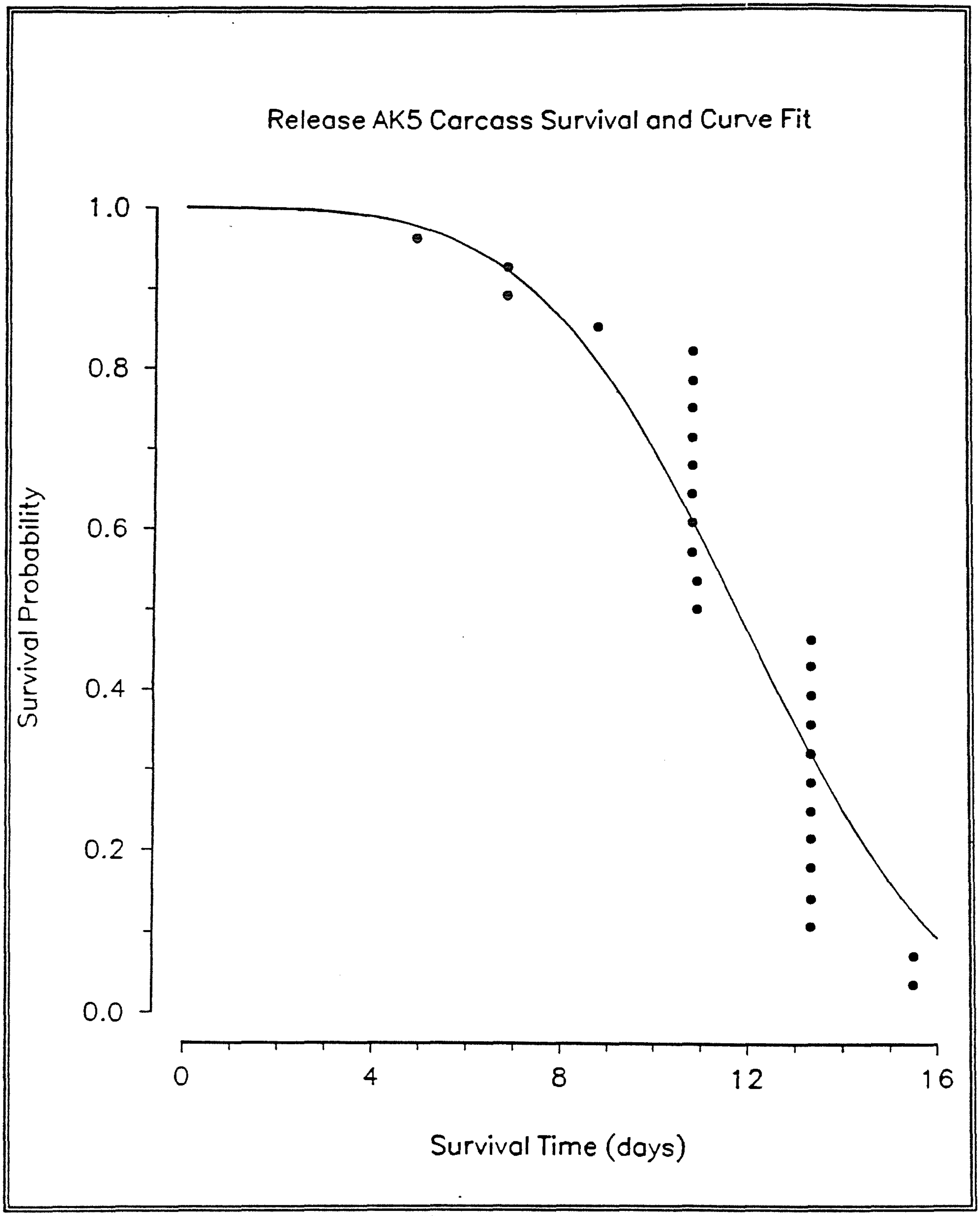


Figure E-1. Fit of the Weibull distribution to the carcass loss data from release AK-5 ($\hat{\lambda} = 3.72 \times 10^{-5}$; $\hat{\gamma} = 3.99$).

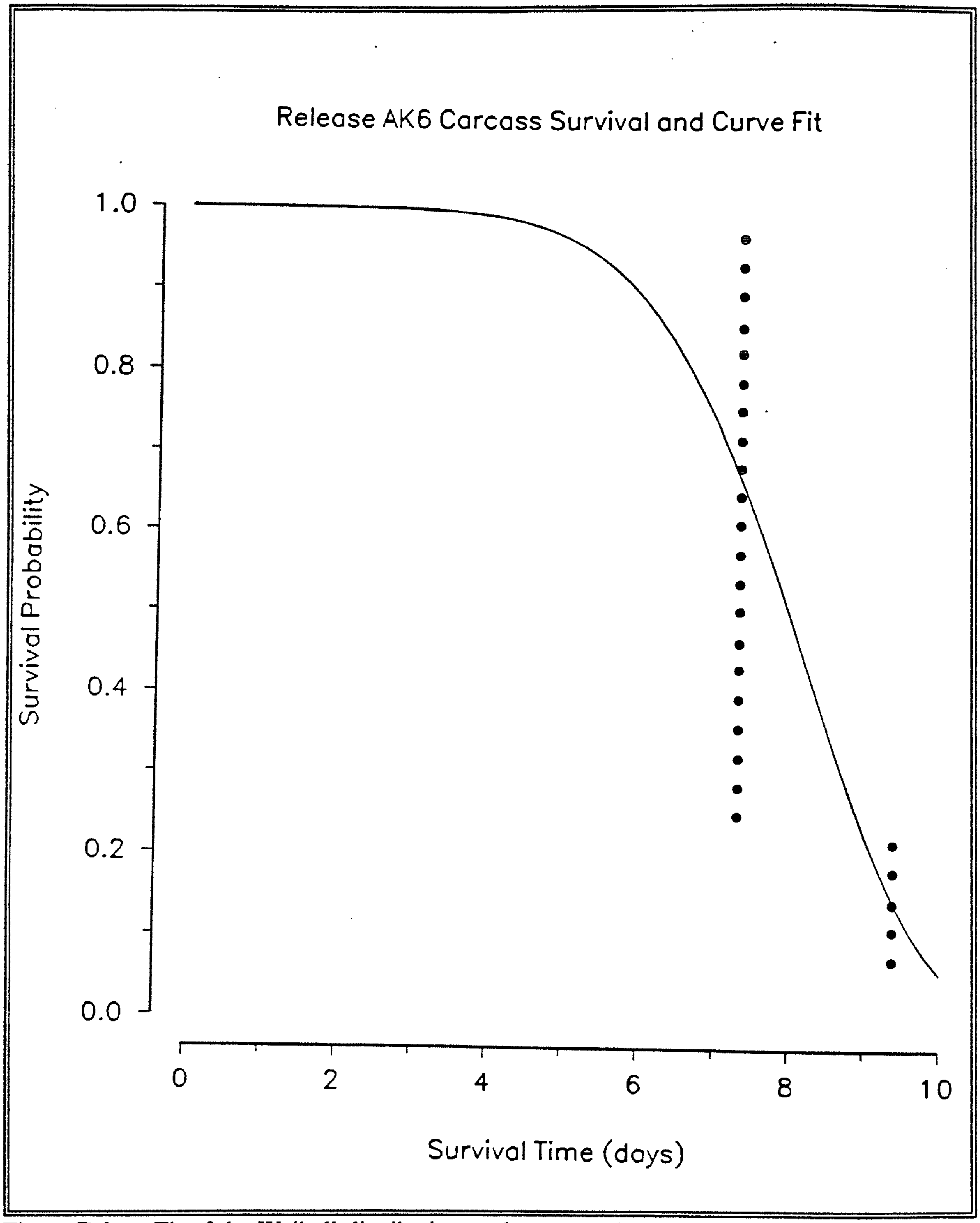


Figure E-2. Fit of the Weibull distribution to the carcass loss data from release AK-6 ($\hat{\lambda} = 1.52 \times 10^{-6}$; $\hat{\gamma} = 6.28$).

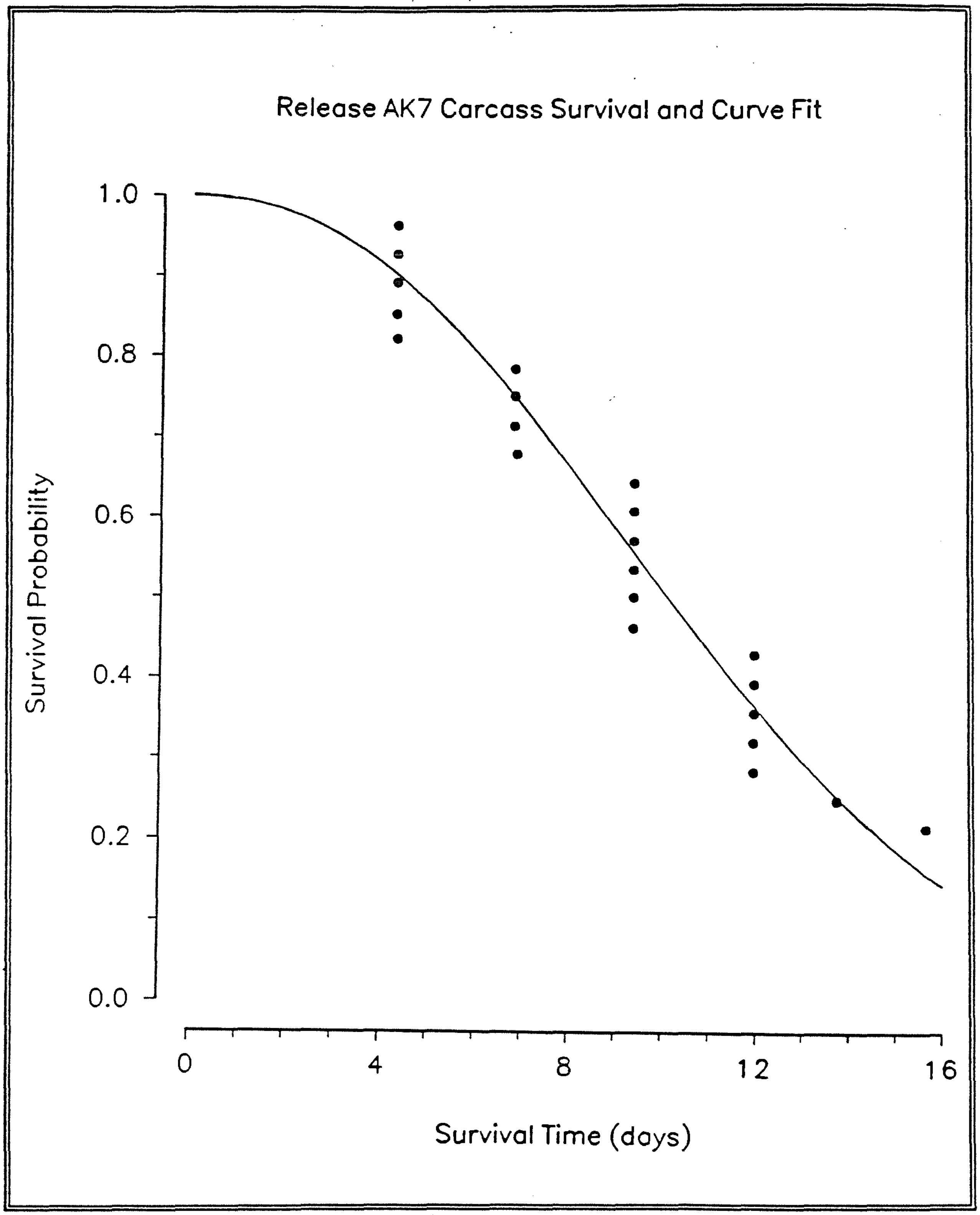


Figure E-3. Fit of the Weibull distribution to the carcass loss data from release AK-7 ($\hat{\lambda} = 3.89 \times 10^{-3}$; $\hat{\gamma} = 2.24$).

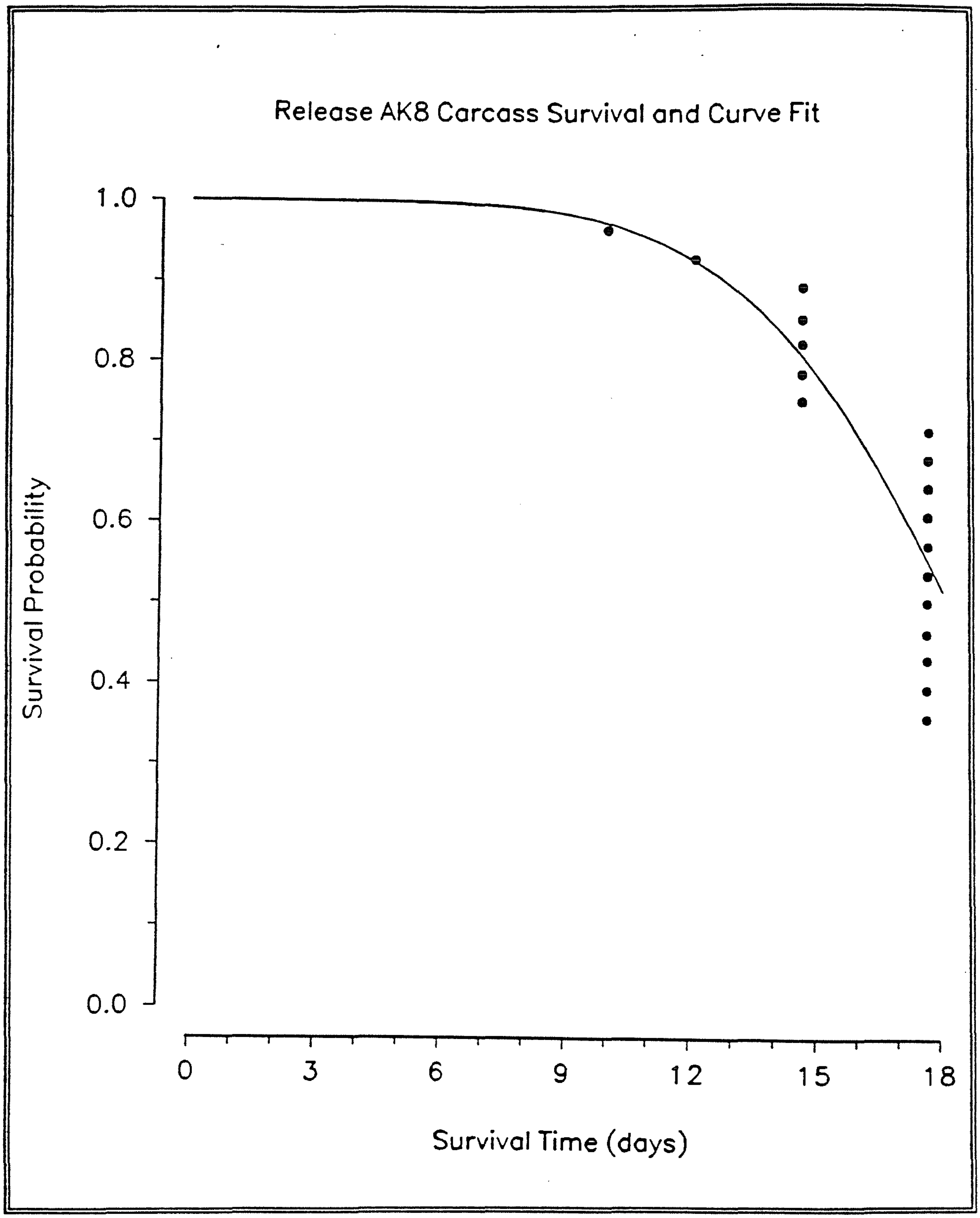


Figure E-4. Fit of the Weibull distribution to the carcass loss data from release AK-6 ($\hat{\lambda} = 1.24 \times 10^{-7}$; $\hat{\gamma} = 5.36$).

APPENDIX F:
LITERATURE CITED

Bibby. C.J. 1981. An experiment on the recovery of dead birds from the North Sea. Ornis Scandinavia 12:261-265.

Calkins, D.J. 1990. Review of literature on intertidal habitat use by black bear. Natural Resource Damage Assessment, Terrestrial Mammal Study No. 2.

Calkins, D.J., and J.P. Lewis. 1990. Assessment of the *Exxon Valdez* oil spill on brown bear populations on the Alaska Peninsula. Natural Resource Damage Assessment, Terrestrial Mammal Study No. 4.

Conover, W.J. 1980. Practical Nonparametric Statistics. Wiley and Sons. New York, New York.

DeGange, A. R., and G. A. Sanger. 1986. Marine birds. Pp. 479-524 In: D. W. Hood and S. T. Zimmerman (eds.). The Gulf of Alaska, physical environment and biological resources. Minerals Management Service Publ. OCS-MMS 86-0095. Washington, D. C. Govt. Printing Office.

Dobbin, J. A., H. E. Robertson, R. G. Ford, K. T. Briggs, and E. H. Clark II. 1986. Resource damage assessment of the *T/V Puerto Rican* oil spill incident. Unpublished Report, James Dobbin Associates, Inc., Alexandria, VA.

Dwyer, T.J., P. Isleib, D.A. Davenport, and J.L. Haddock. 1975. Marine bird populations in Prince William Sound, Alaska. Unpublished Report, Anchorage, Alaska, U.S. Fish and Wildlife Service.

Ford, R. G. 1984. Southern California Marine Mammal and Seabird Risk Analysis. Final Report prepared for the Minerals Management Service, U. S. Department of the Interior, by Ecological Consulting. Contract # 14-12-0001-30224. 240 pp.

Ford, R. G., J.L. Casey, C.L. Hewitt, D.B. Lewis, D.H. Varoujean, D.R. Warrick, and W.A. Williams. 1991. Draft final report: seabird mortality resulting from the Nestucca oil spill incident, winter 1988-89. Prepared for Washington Department of Wildlife. 77 pp.

Ford, R. G., G. W. Page, and H. R. Carter. 1987. Estimating mortality of seabirds from oil spills. Pp. 848-851. In: Proc. 1987 Oil Spill Conference. American Petroleum Institute, Washington, D. C.

Forsell, D. J., and P. J. Gould. 1981. Distribution and abundance of marine birds and mammals wintering in the Kodiak area of Alaska. U. S. Fish and Wildlife Service, Office Biol. Serv. FWS/OBS-81/13. Washington, D. C.

Gould, P.J., D.J. Forsell, and C.J. Lensink. 1982. Pelagic distribution and abundance of seabirds in the Gulf of Alaska and eastern Bering Sea. Washington, D.C., Department of the Interior, U.S. Fish and Wildlife Service. FWS/OBS-82/48.

Gross, A.J., and V.A. Clark. 1975. Survival Distributions: Reliability Applications in the Biomedical Sciences. Wiley and Sons. New York, New York.

Gundlach, E.R., C.D. Getter, and M.O. Hayes. 1980. Sensitivity of Coastal Environments to Spilled Oil. Strait of Juan de Fuca and Northern Puget Sound. Prepared for NOAA, Contract No. NA79RAC0016.

Hayes, M.O., and C.H. Ruby. 1979. Oil Spill Vulnerability Index Maps, Kodiak Archipelago. Unpublished maps. 47 leaves.

Hayes, M.O., P.J. Brown, and J. Michel. 1976. Coastal Morphology and Sedimentation, Lower Cook Inlet, Alaska, with Emphasis on Potential Oil Spill Impacts. Coastal Research Division, Dept. of Geology, Univ. of South Carolina, Columbia. Technical Report No. 12-CRD. 107 pp.

Hope-Jones, P., G. Howells, E. I. S. Rees, and J. Wilson. 1970. Effect of the *Hamilton Trader* oil on birds in the Irish Sea in May 1969. Brit. Birds 63: 97-110.

Irons, D.B., D.R. Nysewander, and J.L. Trapp. 1988. Prince William Sound Waterbird distribution. Unpublished Report, Anchorage, Alaska, U.S. Fish and Wildlife Service.

Michel, J., M.O. Hayes, and P.J. Brown. 1978. Application of an Oil Spill Vulnerability Index to the Shoreline of Lower Cook Inlet, Alaska. Environ. Geol. 2: 107-117.

Orth, D.J. 1971. Dictionary of Alaska Place Names. Geological Survey Professional Paper No. 567. U.S. Government Printing Office. 1,084 pp.

Page, G. W., and H. R. Carter (eds.). 1986. Impacts of the 1986 San Joaquin Valley crude oil spill on marine birds in central California. Unpubl. Report, Point Reyes Bird Observatory, Stinson Beach, CA.

Page, G. W., H. R. Carter, and R. G. Ford. 1990. Numbers of seabirds killed or debilitated in the 1986 *Apex Houston* oil spill in central California. Studies in Avian Biology 14:164-174.

Piatt, J. 1989. *Exxon Valdez* oil spill study: Seabird and Oil pollution surveys conducted from the *MV Tiglax* in the NW Gulf of Alaska, 1-7 May, 1989. USFWS. Unpublished report.

Piatt, J. F., C. J. Lensink, W. Butler, M. Kendziorek, and D. R. Nysewander. 1990. Immediate impact of the *Exxon Valdez* oil spill on marine birds. The Auk 107: 387-397.

Research Planning Institute (RPI), Inc. 1983. Sensitivity of Coastal Environments and Wildlife to Spilled Oil, Prince William Sound, Alaska, an Atlas of Coastal Resources. Prepared for NOAA, Office of Oceanography and Marine Services, Seattle, WA. 48 leaves.

Research Planning Institute (RPI), Inc. 1985. Sensitivity of Coastal Environments and Wildlife to Spilled Oil, Cook Inlet/Kenai Peninsula, Alaska: An Atlas of Coastal Resources. J. Michel and T.G. Ballou, RPI/ESI/8570. Columbia, SC. 57 maps.

Sanger, G.A. 1989. Seabird surveys between Kachemak Bay and southern Kodiak Island, September - October 1989. Draft report of the U. S. Fish and Wildlife Service, Anchorage, Alaska.

Schempf, P.F. 1990. Assessing the effects of the *Exxon Valdez* oil spill on bald eagles. Natural Resource Damage Assessment, Bird Study No. 4.

Sokal, R.R., and F.J. Rohlf. 1981. Biometry. W.H. Freeman and Co., San Francisco, California.

Sowls, A. L., S. A. Hatch, and C. J. Lensink. 1978. Catalog of Alaskan Seabird Colonies. U. S. Fish and Wildlife Service, Office Biol. Serv. FWS/OBS-78/78.

Torgrimson, G.M. 1981. A comprehensive model for oil spill simulation. Proceedings of the 1981 Oil Spill Conference. American Petroleum Institute, Washington, D.C. pp. 423-428.