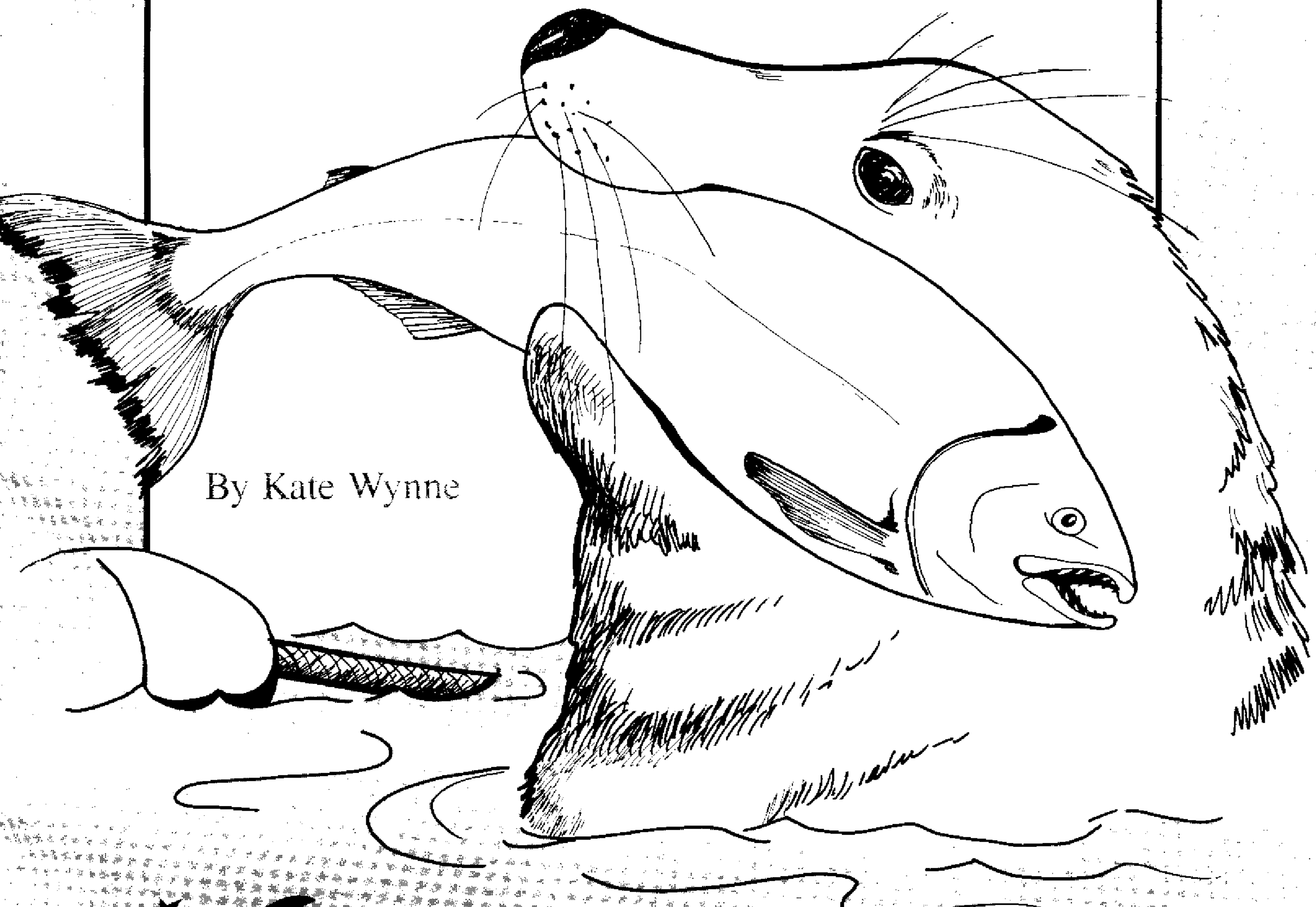
Marine Mammal Interactions with the Salmon Drift Gillnet Fishery on the Copper River Delta, Alaska 1988-1989



By Kate Wynne

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About The Author

Kate Wynne is serving as 1990-91 Alaska Sea Grant Marine Advisory agent in Cordova. Her area of research is mammalian predators. She has nine years experience documenting commercial fishing-mammal interactions on both the East and West coasts of the United States.Wynne holds a master's degree in wildlife management from the University of Maine, where she worked as a faculty research associate from 1981 to 1987.

Author Kate Wynne notes the condition of a dead harbor seal she found washed up on shore on the barrier islands in the Copper River Delta, June 1989. She took several tissue samples for environmental contaminant analysis. Wynne suspects this seal died from a gunshot wound. Photo by D. Schneider.

ABSTRACT

Marine mammal interactions with the salmon drift gillnet fishery on the Copper River Delta, Alaska were examined in 1988 and 1989 using field observations, dockside interviews, and beached carcass surveys. Past and present conflicts include scavenging of netted salmon and damaging gillnets by pinnipeds, and incidental and intentional killing of marine mammals because of net encounters. The frequency and nature of marine mammal-drift net conflicts on the Copper River Delta varied geographically and seasonally with the species involved.

Northern sea lion conflicts occurred predominantly in May and early June and were most frequent in surf and nearshore waters. Harbor seal conflicts were most severe in August in surf and channels and often involved recently weaned pups. Sea otter-drift net encounters were most frequent when mother-pup pairs and fishermen were using the same tidally restricted channels in the western region of the delta. Porpoises and other cetaceans were incidentally caught in drift nets set in nearshore and offshore waters throughout the delta.

A conservative estimate of financial loss due to pinniped depredation on salmon on the Copper River Delta in 1988 represents less than 1% of the ex-vessel value of salmon landed. Incidental and intentional marine mammal takes were too infrequent and dispersed to establish a realistic estimate of fishery-wide take rates. Based on comparisons with 1978 take rates, our data show a significant reduction in drift net-related intentional killing of pinnipeds. While not statistically different, the number of sea otter-drift net encounters on the Copper River Delta increased between 1978 and 1988 and will likely continue as sea otters increase. The successful release of entangled sea otters and cetaceans shows that not all incidental captures are lethal and demonstrates the need and feasibility of informing fishermen of nonlethal removal techniques.

A larger, stratified sampling effort is required to estimate realistic fishery-wide take and mortality rates.

INTRODUCTION

Marine mammals interact with commercial fisheries as competitors for prey species (Lowry et al. 1982, Johnson 1982, Melteff and Rosenberg 1984) and through direct conflict with fishing gear (IUCN 1981, Contos 1982). Gear conflicts occur most frequently in fixed-gear and drift net fisheries (Mate 1980, Newby 1982, Beach et al. 1985, Gilbert and Wynne 1985) and include incidental entanglement, predation on catch, and resulting gear damage.

In Alaska, conflicts between salmon drift gillnet fisheries and coastal pinnipeds have occurred for decades. Direct conflicts and perceived competition with harbor seals (*Phoca vitulina richardsi*) and northern sea lions (*Eumetopias jubatus*) historically have been intensive in the Copper River area. From 1951 to 1958, the Territory of Alaska Department of Fisheries killed more than 30,000 harbor seals on the Copper River Delta to reduce predation on salmon stocks (Lensink 1958, Matkin and Fay 1980).

Marine mammals were granted federal protection in 1972 by the Marine Mammal Protection Act (MMPA). Intentional killing was thereafter limited to harvest by Natives and scientific collection and defense of commercial fishing gear. Since passage of the MMPA, the economic value of the Prince William Sound and Copper River salmon fishery increased from approximately $2 million to the current $68 million record set in 1988, according to the Alaska Department of Fish and Game (ADFG). The increased value of the salmon fishery coupled with reduced legal means of controlling competition with marine mammals have exacerbated conflicts on the Copper River Delta.

The first documented marine mammal conflicts on the Copper River Delta was presented by Imler and Sarber (1947). They examined nearly 11,000 salmon gillnetted on the Copper River Delta and estimated that approximately 2% of the catch was damaged by harbor seals. Damage caused by northern sea lions was not mentioned.

In 1978, Matkin and Fay (1980) reassessed conflict levels between marine mammals and salmon drift net fishermen in the Copper River Delta and Prince William Sound. They found marine mammal depredation reduced the value of the salmon harvest by approximately 2.3%. Losses to fishermen were estimated at nearly $350,000. In addition, they estimated that 1,000 marine mammals were caught or killed that year—500 harbor seals, 400 northern sea lions, 100 porpoises and sea otters—in the course of drift net fishing activities.

Significant changes in the biological and legal status of several marine mammals prompted a re-evaluation of marine mammal-drift net conflicts on the Copper River Delta. Surveys in the western Gulf of Alaska and Aleutian islands indicate northern sea lion numbers declined 52% between 1958 and 1985 (Merrick et al. 1987, Calkins and Goodwin 1988) and 63% between 1985 and 1989 (Loughlin et al. 1990). The legal status of the northern sea lion was declared "threatened" by emergency rule of the National Marine Fisheries Service (NMFS) on 5 April 1990 (Federal Regulation 55[66]:12645-12662). In addition, recent surveys suggest harbor seal numbers are declining in the western Gulf of Alaska, following a geographic pattern similar to that of the northern sea lion (Pitcher 1989). While declines in both species are centered west of the Copper River Delta and have not been attributed to fishing mortality, their precipitous and eastward progress has raised concerns throughout their ranges.

In contrast, sea otters (*Enhydra lutris*) are increasing in abundance in eastern Prince William Sound and are anticipated to encounter salmon drift nets with increased frequency as they extend their range eastward into the Copper River region. Preliminary findings by Simon-Jackson (1986, 1987) in this area suggest such conflicts were more frequent in 1986 and 1987 than during the 1978 drift net season (Matkin and Fay 1980).

The present study was initiated in response to these concerns and the need to identify the nature and extent of marine mammal conflicts with salmon drift net fishermen on the Copper River Delta. Faced with growing political pressure and the belief that current drift net-related pinniped mortality is significantly lower than the 1978 estimate, Copper River Delta drift net fishermen encouraged this re-evaluation of conflict levels.

In 1989, the Prince William Sound-Copper River drift gillnet fishery was declared a Category I fishery based on its history of frequent marine mammal interactions. Under the 1988 MMPA amendments, fishermen in Category I are required to record and report marine mammal interactions and are subject to an observer program after 20 July 1989. In addition, the MMPA amendments prohibited the intentional killing of northern sea lions and limited incidental take to 1,350 northern sea lions per year in all fisheries. The annual incidental take quota was subsequently reduced to 675 west of 141° W longitude when northern sea lions were listed as threatened. Provisions of the 1988 MMPA amendments were not effected during the course of this study. Study objectives were to:

- Identify and quantify current marine mammal conflicts with salmon drift net fishermen on the Copper River Delta.
- Compare findings to results of Matkin and Fay (1980) to determine changes in marine mammal conflicts since 1978.
- Evaluate or develop methods for quantifying, verifying, and mitigating take levels and gear and salmon losses.

Objectives of the study were modified in 1989 to focus on sea otter-drift net conflicts. Consequently, field sampling emphasized observation of conflicts in the western portion of the study area.

On March 24, 1989, the tanker *Exxon Valdez* ran aground on Bligh Reef in Prince William Sound, approximately 60 km northwest of the study area. Because the oil drifted south and west out of Prince William Sound, neither the study area nor the salmon drift net fishery on the Copper River Delta were directly affected by spilled oil. Fishing in the area was indirectly affected, however, as many fishermen chartered their vessels and services to clean up the spill instead of fishing. The indirect effects of the oil spill on marine mammals of the Copper River Delta are unclear and are not addressed in this report.

This study was designed and conducted as a cooperative research effort between the University of Alaska Sea Grant College Program, state and federal marine mammal managers, and the salmon drift net fishermen of Cordova, Alaska. Funding was provided by the University of Alaska Sea Grant College Program and the U.S. Fish and Wildlife Service (USFWS). Additional logistic and laboratory support was provided by the ADFG, NMFS, the U.S. Forest Service (USFS), and Dr. Chuck Monnett, research associate at Alaska Pacific University. Cindy Macklin and Jill Anthony provided excellent, reliable field assistance under harsh conditions. The expert flying and observational services of pilot Steve Ranney were fundamental to the completion of safe and reliable surveys. Rick Steiner, University of Alaska Sea Grant Marine Advisory Program agent, provided a critical link between the project and local drift net fishermen and offered invaluable consultation. Mimi Hogan, Jon Nickles, and Terri Simon-Jackson, all with the USFWS, and Ron Dearborn, director of the Alaska Sea Grant College Program, provided organizational, logistical, and contractual support throughout the project. Finally, I would like to thank the fishermen of Cordova, Alaska for their cooperation and participation in this study.

STUDY AREA

The Copper River Delta is located in northern Gulf of Alaska, east of Prince William Sound. In this study, the Copper River Delta is considered to include all portions of Orca Inlet, Copper River, Bering River, and Gulf of Alaska that are open to commercial salmon drift net operations (Fig. 1).

The Copper River Delta is characterized by extensive intertidal sand flats, tidally restricted channels, and gently sloping offshore bathymetry. (In tidally restricted zones water is limited to the channels at low tide but floods the flats at high tide.) The Copper River and adjacent Orca Inlet join the Gulf of Alaska over a series of shallow bars between barrier islands (Fig. 1). Regions of surf and swell activity occur where waves are driven into the bars and barrier islands. The Bering River drains into Controller Bay east of the Copper River. This area has wooded rather than sand barrier islands and minimal surf and swell activity.

Because the Copper River and Bering River carry a high sediment load (NEGOA 1980), visibility in the waters of the delta is restricted and turbidity extends several miles offshore. Sediment deposition has created a gentle offshore slope with water depths of 50 fathoms up to 16 km offshore.

The combination of freshwater discharge and a tidal amplitude of 5.5 m results in strong currents in the channels of the delta. Outside the barrier islands, current direction is influenced by freshwater transport, winds, and the predominant western flow of the Alaska Coastal Current (Royer et al. 1979, Ahlnas et al. 1987).

The study area includes portions of the Copper River Delta from Hook Point on Hinchinbrook Island east approximately 120 km to Controller Bay (Fig. 1). ADFG divides the area into six major units for management of commercial fishing activities within the Copper River and Bering River fishing districts: West 212-10, Central 212-20, East 212-30, and Bering River 200-10, 200-20, and 200-30 (Fig. 2). In addition, the study recognizes four habitat subunits that reflect distinct fishing zones and unique habitat qualities. These habitat zones are defined as channel, surf, nearshore, and offshore (Fig. 2). Channel areas extend upstream from the barrier islands and represent tidally restricted zones of relatively protected waters. Surf occurs immediately seaward of the barrier islands and is characterized by swells and extensive breakers. The nearshore zone is defined to include waters from the surf zone out to 10-fathom depths. The offshore zone includes waters deeper than 10 fathoms. Fishing strategies and boat design vary between zones.

Description of the Fishery

A limited entry salmon drift gillnet fishery is conducted on the Copper River Delta from early May to late September. The early spring salmon fishery in these districts targets primarily sockeye (*Oncorhynchus nerka*) and chinook salmon (*O. tschawytscha*) returning to spawn in the Copper River. These runs diminish by mid-summer and by early August fishermen primarily target coho salmon (*O. kisutch*) returning to both river systems. No major runs of pink (*O. gorbuscha*) or chum (*O. keta*) salmon occur in these districts.

Permit holders in this fishery are entitled to fish in Prince William Sound and the Copper River Delta. Approximately 500 of the drift gillnet fishermen concentrate in the Copper River district until mid-June. Drift net effort then declines on the delta as Prince William Sound fishing districts are opened. As coho salmon appear on the Copper River Delta in August, fishing effort increases again within the study area.

Commercial salmon fishing periods are established by order of the regional ADFG commercial fisheries manager. Timing, location, and duration of commercial salmon fishing periods is based on species escapement. In the Copper River and Bering River districts in 1988 and 1989, there were up to two fishing periods per week lasting 12 to 72 hours each.

Boats involved in the fishery are approximately 6 to 10 m long. They are categorized as

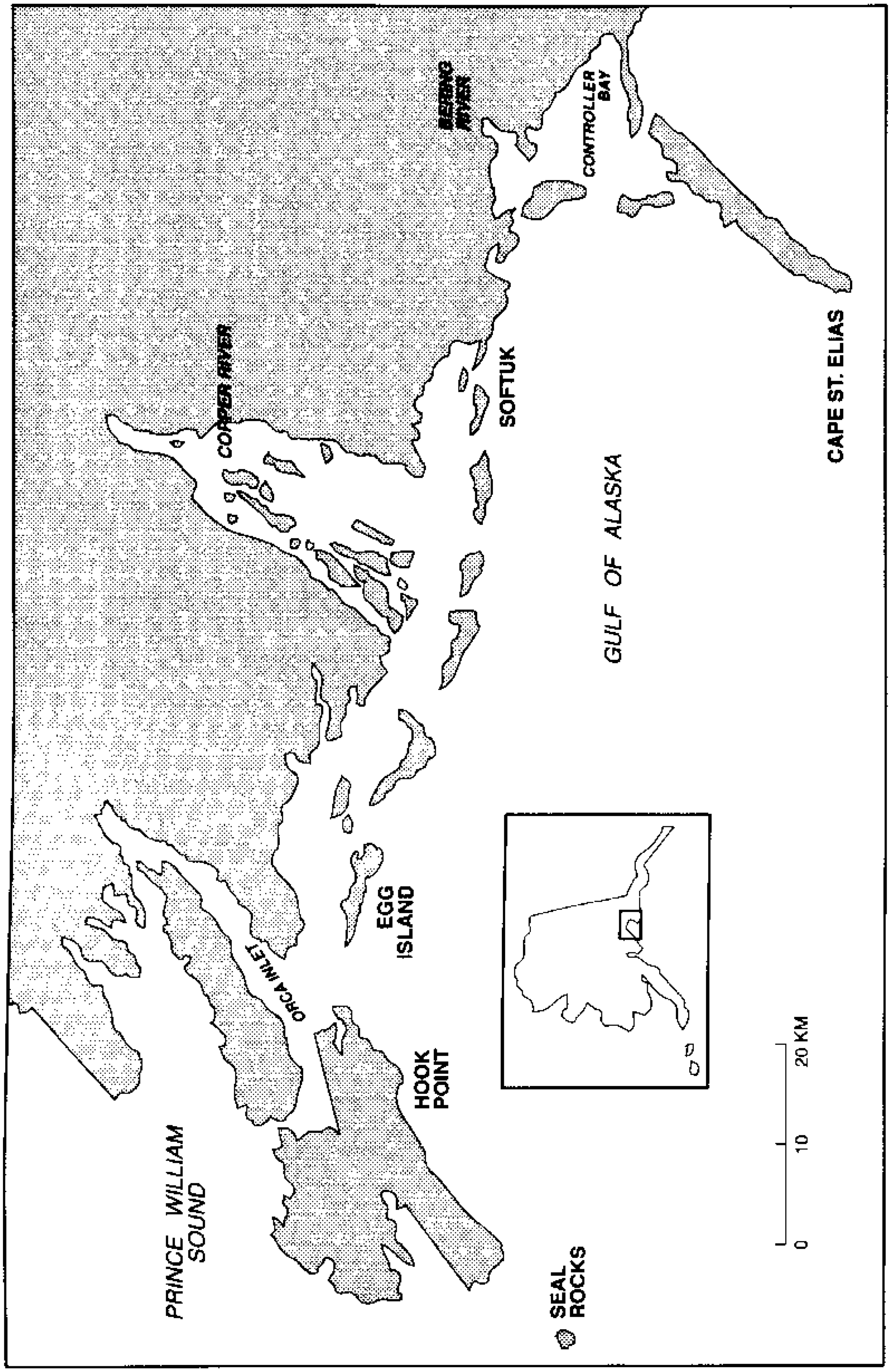

Figure 1. Location of study area on the Copper River Delta, Alaska.

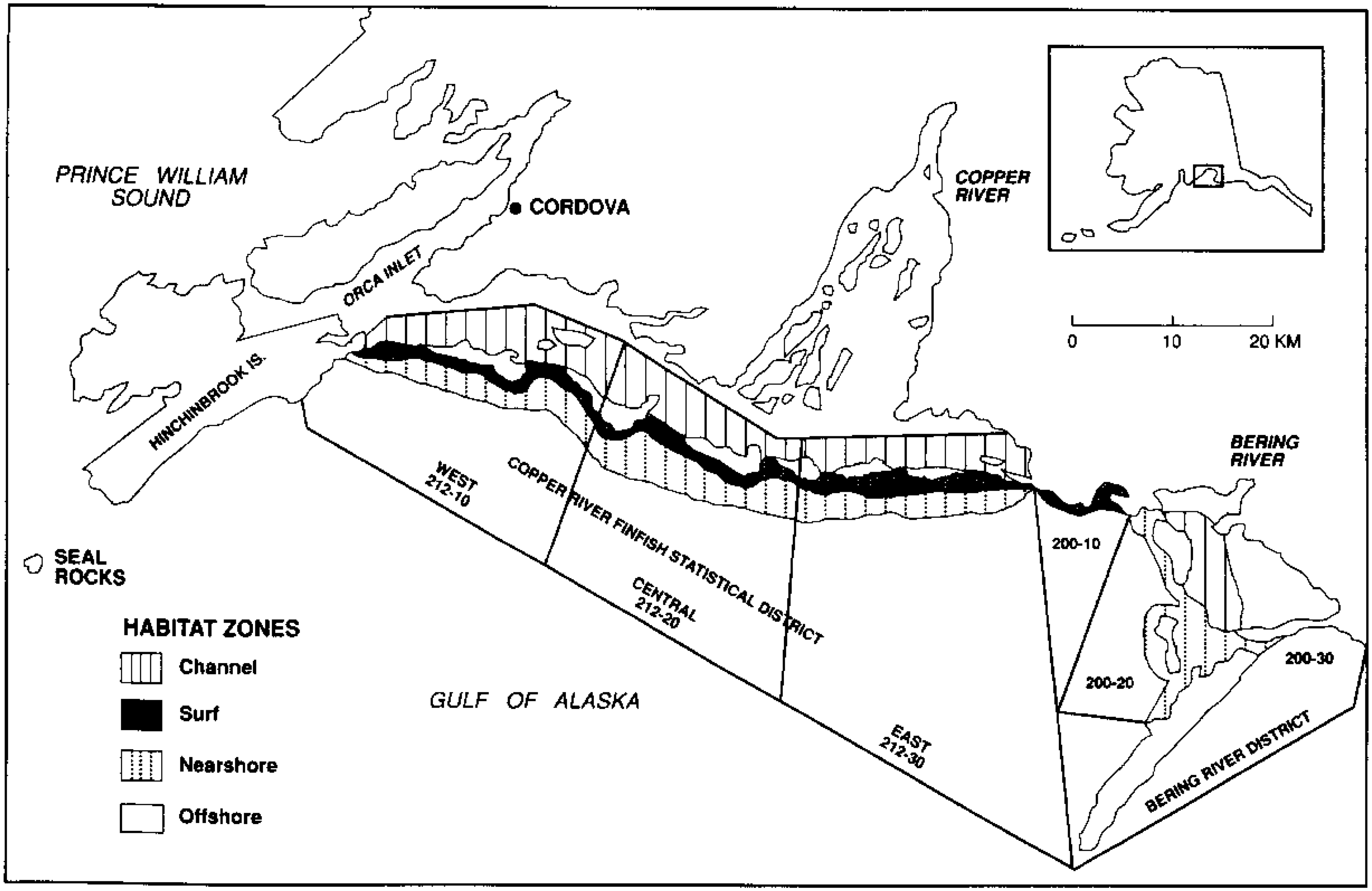

Figure 2. Approximate location of habitat zones and Alaska Dept. of Fish and Game management units in the Copper River and Bering River fishing districts on the Copper River Delta.

bowpickers or sternpickers depending on whether the net is deployed and retrieved over the bow or the stern. Each boat fishes one drift net constructed of polyfilament mesh and hung at the water's surface by floats on a corkline. Mesh size varies with the species targeted and by ADFG regulation. In 1988, mesh size was limited to a maximum of 6 inches between May 23 and August 1 in an effort to protect chinook stocks. Drift nets are legally restricted in length to no more than 273 m (150 fathoms) but vary in depth according to the area being fished. Drift nets are set for periods of 15 minutes to 3 hours and are tended by the fisherman.

Marine Mammals in the Area

Waters of the Copper River Delta support a diversity of marine mammals. Northern sea lions and harbor seals are common in the area, as are sea otters. Transient and resident cetaceans include the harbor porpoise (*Phocoena phocoena*), Dall's porpoise (*Phocoenoides dalli*), killer whales (*Orcinus orca*), minke whales (*Balaenoptera acutorostrata*), gray whales (*Eschrichtius robustus*), and humpback whales (*Megaptera novaeangliae*).

Several traditional pinniped haul-outs and rookeries have been identified in and near the study area (Pitcher and Vania 1973). Thousands of harbor seals use sandbars in the Copper River as haul-outs and pupping sites. A rookery at Cape St. Elias and haul-out at Seal Rocks (Fig. 1) support about 4,000 northern sea lions seasonally.

An estimated 4,000 to 6,000 sea otters occur in the Prince William Sound-Orca Inlet region (Calkins and Schneider 1985). More than 3,000 sea otters are found seasonally in Orca Inlet and the Egg Island area (Monnett and Rotterman 1988, Wynne 1989).

Although porpoises are seen frequently in waters outside the barrier islands, estimates for the abundance of both Dall's and harbor porpoise are lacking for the Copper River Delta.

METHODS

Field Sample

During the first fishing period in 1988, project personnel monitored marine mammal conflicts by observing fishing activities from the USFWS R/V *Starik* in a manner similar to that used by Matkin and Fay (1980). This technique was discontinued thereafter because it proved an inefficient and less effective means of observing fishing activities.

As a working, cooperative relationship developed with the fishermen, use of at-sea observers aboard the drift net vessels became a sampling option. After the first fishing period, data were collected by observers aboard drift net vessels actively fishing within the study area.

Each observation made during field sampling represents the time during which one drift net was set, fished, and retrieved (hereafter referred to as a "net observation." In Matkin and Fay's study (1980), separate observations were made of randomly selected vessels. In this study, each observer remained aboard one vessel for the duration of the fishing period and recorded data from consecutive sets made by that boat. When possible, previously unsurveyed vessels were surveyed each fishing period.

Several variables recorded during each observed set of a net were comparable to those collected by Matkin and Fay (1980). Variables included the number of salmon caught, the amount of salmon and gear damaged by marine mammals, and of incidental and intentional marine mammal take. Hereafter, "take" is considered to include capture, injury, or death. In addition, data were collected on the number and behavior of marine mammals in and near the drift net, the use and effectiveness of marine mammal deterrents, and a detailed description of the drift net's location.

Salmon damage rates were determined using field observations and dockside surveys. Damaged salmon observed during field sampling were categorized as "seal-damaged," "sea lion-damaged," or "damage-unknown" based on characteristic scavenging patterns (Matkin and Fay 1980) and presence of marine mammals near the net. Sea lions typically remove the salmon completely or leave only the head. Harbor seals often chew on the head or caudal region of the salmon. Salmon bearing old or indistinguishable injuries were categorized as damage-unknown.

The proportion of the catch damaged by marine mammals was calculated and applied to total landings to estimate the level of salmon damage sustained by the fishery. The economic value of salmon damaged by marine mammals was calculated using differential loss constants determined for marketable and unmarketable salmon. No effort was made to estimate the number or value of salmon removed from the net without evidence.

Gear damage rate was determined from the field sample and assessed as the ratio of square feet of drift net damaged per salmon landed. Because the source of new holes in drift nets is often difficult to ascertain, only damage following marine mammal presence was attributed to marine mammals. The monetary loss to the fishery due to marine mammal-caused drift net damage was estimated by applying sampled damage rates to total landings, and multiplying by an approximated repair fee of $5 per square foot using a formula similar to Matkin and Fay's (1980). The frequency of gear damage reported and observed in these samples was insufficient to allow testing of differences among week, management unit, and zone.

The presence of marine mammals in and near drift nets was recorded during the field sample. If the animal was seen within 5 m of the net or approaching with apparent interest, it was recorded as "working the gear." Other marine mammals seen within 1 km of the gear but avoiding or showing no interest in the gear were recorded separately. Each category of marine mammal involvement was summarized and examined separately to determine spatial and temporal patterns of frequency. Techniques employed to deter or chase marine mammals from drift nets and their apparent success were recorded in order to calculate the relative frequency of success for each deterrent.

Marine mammals taken incidentally and intentionally in the field sample were categorized as "captured/dead," "captured/released alive," or "killed directly." Marine mammal take rates were summarized for each category. A mortality rate estimate was calculated as the number of marine mammals killed incidentally or intentionally per net observation.

Dockside Sample

In 1988, drift net fishermen were interviewed on the docks as they returned to Cordova or from cannery tenders on the fishing grounds. Questions similar to those posed by Matkin and Fay (1980) were asked of fishermen. The reports summarized activities and interactions for the entire fishing period. Fishermen often displayed evidence of salmon or net damage experienced during that fishing period.

Information fishermen provided on drift net harassment, salmon damage, and marine mammal interactions was summarized in a manner similar to the field sample. In addition to differentiating between harbor seal- and sea lion-caused damage, interviewed fishermen were asked to report the number of fish in each category that were marketable and unmarketable. From these reports, it was possible to estimate the relative cost of damage caused by each marine mammal species.

Fishermen were also requested to report the number and species of marine mammals seen, caught incidentally, and killed intentionally during the fishing period. The proportion of vessels reporting marine mammal mortality in the dockside survey was compared to the proportion calculated from Matkin's 1980 dockside survey to test the hypothesis that mortality rates were the same in 1978 and 1980 ($\alpha = 0.05$) (Zar 1974).

Several unsolicited reports of marine mammal interactions were received by project personnel. Although they were anecdotal in nature and not included in quantification of conflicts, these reports identified conflicts not detected by structured sampling.

Beached Carcass Survey

Surveys to locate beached carcasses have been used to document and monitor marine mammal mortality elsewhere in Alaska (Kenyon 1969, Fay et al. 1979). A survey of Copper River Delta beaches for carcasses was initiated in 1988 and continued in 1989 to assess the source and frequency of marine mammal mortality during the salmon fishing season. An aerial survey of the barrier island beaches between Hook Point and Softuk (Fig. 1) was made weekly between fishing periods. During each survey, beached mammals were identified, counted, necropsied when possible, and marked or mapped to prevent recounting.

A preliminary beach survey was conducted the week prior to the first fishing period in each year to mark and identify carcasses present before the fishing season. In 1988, this survey was conducted by observers walking in pairs along the beaches between Hook Point and the middle of Egg Island (Fig. 1). Following this survey, it was determined that a low-altitude aerial search for carcasses would provide a more efficient means of sampling a much larger area with a comparable budget. The 1989 pre-season carcass survey was conducted aerially and covered the beaches from Softuk to Hook Point.

During systematic carcass surveys, a Cessna 180 plane was flown along the tide line at an altitude of 5-20 m and speed of 70-80 knots, and was landed on the beach when a carcass was spotted. The species, sex, estimated age class, and standard measurements of each carcass were recorded. A tooth was extracted for more precise aging. When possible, carcasses were examined to determine cause of death, reproductive condition, and stomach contents. If the carcass was fresh, tissue samples were collected for environmental contaminant analyses. Diagnostic tooth extraction and necropsy techniques used on the carcasses coupled with supplemental flagging and mapping efforts prevented the need for recounting of beached carcasses. Other carcasses that were seen in the study area and reported to project personnel were sought in subsequent flights and recorded as separate observations if they were not found.

Limited verification of the aerial surveys was conducted in 1989. Portions of Strawberry Beach on Hinchinbrook Island were surveyed on foot immediately following aerial surveys of the beach. Paired observers walked along the tide line and examined all debris for concealed or undetected marine mammal carcasses.

A preliminary effort was made in 1988 to determine what proportion of mammals dying on the Copper River Delta wash ashore in the study area. On 9 July 1988, eight marked trawl buoys were air-dropped to four nearshore and four offshore locations from Softuk to Egg Island (Fig. 3). The buoys were modified to simulate the assumed neutral buoyancy of a pinniped carcass. Each was numbered and bore a request for those who saw the buoys to report them to the project coordinator. One buoy was equipped with a radio transmitter set at 164 Mhz. In addition, carcasses of a sea otter and harbor seal pup were tagged and set adrift in the study area. Although resightings of the marked buoys and carcasses were intended to provide information on local drift and beach deposition patterns, the effort was largely unsuccessful.

Fishing and Sampling Effort

Fishing activities (1988 and 1989). The 1988 commercial salmon drift net fishing season began 16 May in the Copper River district and 20 June in the Bering River district. Fishing in both areas ended 13 September. During the season, 520 permit holders fished in the Copper River district; 158 of them also fished in the Bering River district (ADFG statistics). In the Copper River district, 28 fishing periods were open for a total of 900 hours maximum fishing time. The fleet effort of 260,892 permit-hrs (permit-hr = number of vessels x maximum hours each fishing period) resulted in the landing of 1,031,684 salmon in the Copper River and Bering River districts (Table 1).

In 1989, the salmon drift net season began 15 May in the Copper River district and 24 June in the Bering River district. Both areas were closed 29 September. Fishing effort was reduced in 1989 (Fig. 4) as many fishermen chartered their vessels to clean up the *Exxon Valdez* oil spill. During the 1989 season, 476 permit holders fished in the Copper River district; 40 also fished in the Bering River district. In the Copper River district, 25 fishing periods were open for a total of 840 hours. The fleet effort of 177,552 permit-hrs resulted in the landing of 1,301,148 salmon in the Copper River and Bering River districts.

Ex-vessel prices for salmon reached record highs in 1988, more than doubling the 1978 (Matkin and Fay 1980) price for all species. In 1989, ex-vessel prices dropped significantly, with the average value of coho salmon roughly half the 1978 value (Table 2).

Field sample (1988 and 1989). In 1988, project personnel made observations from 22 different drift net vessels fishing in the Copper and Bering River districts. Sampling effort covered 23 of the 28 fishing periods and resulted in the observation of 327 sets during the 966 permit-hrs surveyed (Table 1). Total landings of salmon (5,807) observed during field sampling represented 0.6% of the fleet's total landings in the Copper River and Bering River districts.

As a result of the opportunistic use of drift net vessels as observation platforms, the spatial distribution of samples could not be controlled in 1988. Although sampling effort was fairly evenly distributed among the west, central, and east areas, twice as many observations were made in

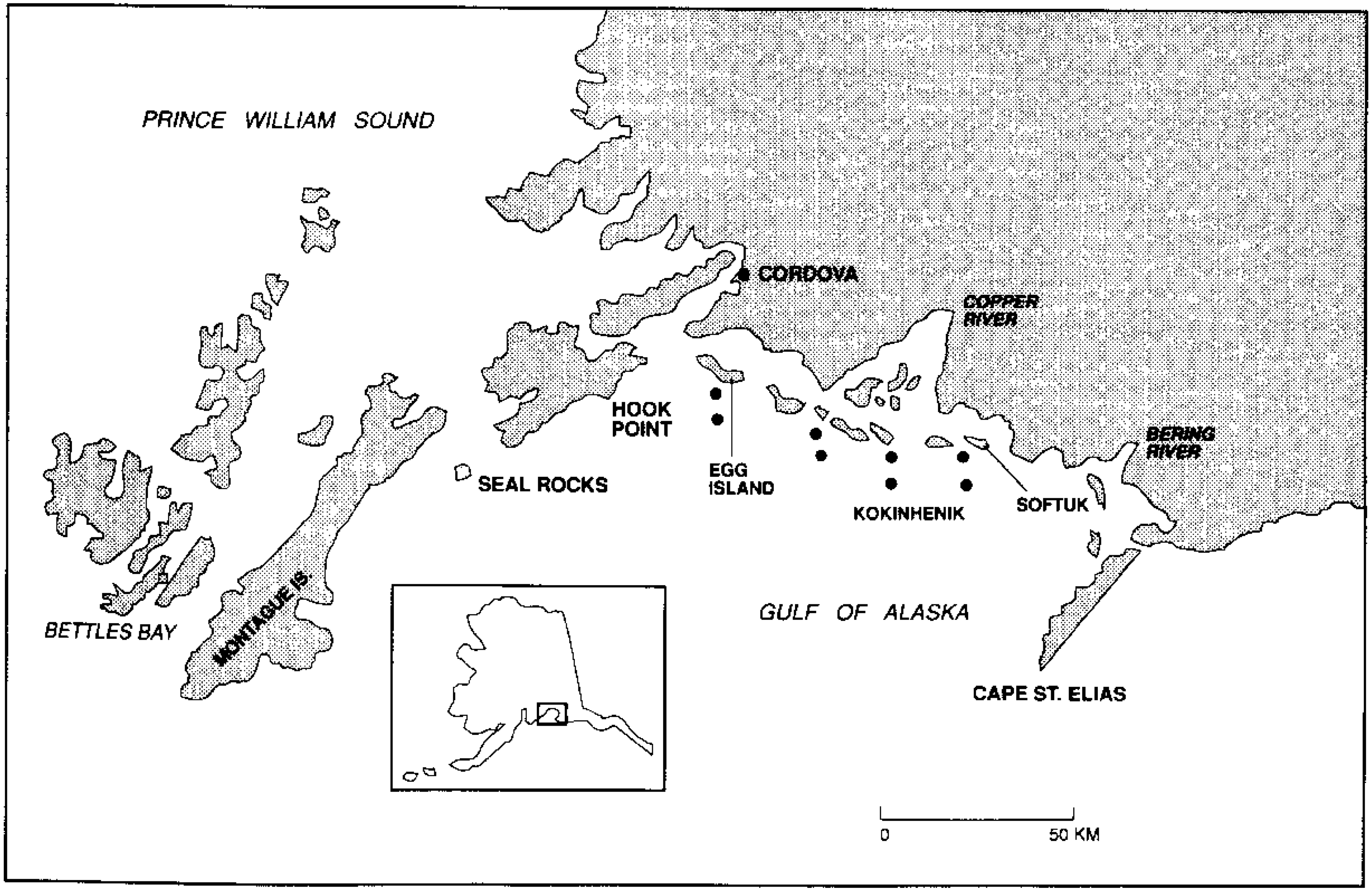

Figure 3. Approximate location of deployment sites (dots) and recovery site (solid square) of trawl buoys used to examine drift patterns from the Copper River Delta, 1988.

Table 1. Weekly summary of drift net effort and sampling effort (field and dockside) in the Copper River and Bering River districts, 1988.

Week starting	Drift net fishing effort[1] Hrs	No. permits landing	Wk total perm-hrs	Sampling effort: Field observations[2] No.	perm-hrs	Dockside interviews[3] No.	perm-hrs
May 16	24	440	10,560	8	12	0	0
May 23	24/36	473/497	29,244	38	120	12	288
May 30	36/12	497/481	23,664	0		22	792
June 6	24	498	11,952	19	48	0	
June 13	24/24	479/433	21,888	29	72	15	360
June 20	24/24	297/309	14,784	33	72	0	
June 27	24/24	89/198	6,888	2	6	0	
July 4	24/24	44/118	3,888	20	48	0	
July 11	24/24	115/205	7,680	19	48	11	264
July 18	24/24	193/212	9,720	0		7	168
July 25	24/24	115/101	5,184	13	48		
Aug 1	24/24	142/50	4,680	7	24		
Aug 8	48	203	9,744	26	96		
Aug 15	72	209	15,048	43	144		
Aug 22	72	288	20,736	45	72		
Aug 29	72	400	28,800	22	144		
Sep 5	72	414	29,808	0			
Sep 12	24	279	6,696	3	12		
Total	900		260,892	327	966	67	1,872

[1] Fishing effort: hrs = hours of maximum fishing time (numbers separated by slash denote two fishing periods in that week); No. permits = number of fishermen landing salmon during that period; wk total perm-hrs (permit-hrs) = sum of maximum fishing hrs x permits for all periods in week.

[2] Field sample: Number of permit-hrs during which an observer was present on board; No. = number of observed set-soak-haul cycles of a drift net.

[3] Dockside sample: number of permit-hrs reported by interviewed fishermen.

channel areas as any other (Table 3). In 1989, field sampling was reduced and weighted toward western portions of the Copper River Delta to meet revised sea otter objectives. Sixty sets were observed from six drift net vessels during six fishing periods, primarily west of Grass Island. Data collected in this limited sample were used to monitor marine mammal take but were not included in calculations of salmon and drift net damage estimates.

Dockside sample (1988). In 1988, salmon drift net fishermen were interviewed either from a cannery tender on the fishing grounds or after they returned to Cordova. A total of 67 interviews representing 1,872 permit-hrs were conducted during five weeks of dockside sampling (Table 1), primarily during the sockeye salmon season. Fishermen were asked to summarize their fishing effort and marine mammal interactions during the previous fishing period. Salmon landings (10,539) reported in interviews represented 1.0% of the fleet's total landings and 2.6% of the salmon landed during those weeks.

Fishing effort that was reported in this sample was distributed throughout the study area

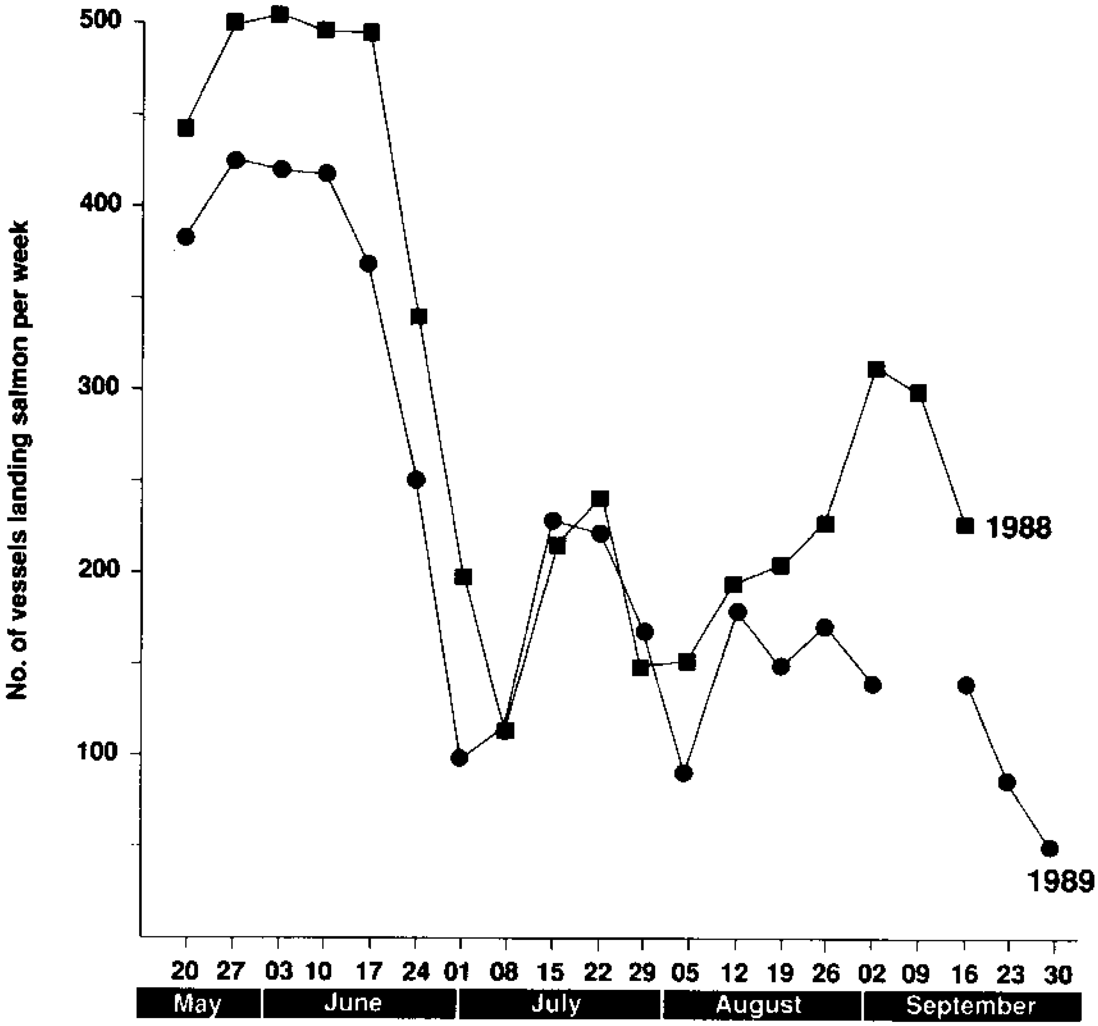

Figure 4. Comparison of salmon drift net effort in the Copper River district in 1988 and 1989. (Statistics from Alaska Dept. of Fish and Game Commercial Fisheries unpublished report.)

and across all habitat zones but sample size was insufficient to test the randomness of the sample (Zar 1974).

Beached carcass survey (1988 and 1989). Weekly systematic aerial surveys of the barrier beaches of the Copper River Delta were completed 36 times during the study, 17 in 1988 and 19 in 1989. Approximately 90 km of shoreline were surveyed each flight. Three aerial surveys were verified on the ground in 1989 by paired observers walking along 3 to 8 km of Strawberry Beach.

RESULTS

Salmon Damage Rates

During the 1988 field survey, 190 of the 5,807 (3.3%) salmon observed bore damage attributable to marine mammals. Of the observed harvest, 174 (3.0%) were damaged by harbor seals while 16 (0.3%) were damaged by northern sea lions.

In the dockside survey, fishermen reported 194 of 10,539 salmon landed (1.8%) were damaged by harbor seals or northern sea lions.

Table 2. Value of salmon species harvested in the Copper River and Bering River districts in 1978, 1988, and 1989.

	1978[1]	1988[2]	1989[3]
Chinook salmon			
avg wt (lb)	27.8	26.5	26.5
price/lb ($)	1.35	3.00	2.25
value/fish ($)	37.50	79.50	59.62
Sockeye salmon			
avg wt (lb)	7.3	6.1	6.8
price/lb ($)	1.25	3.00	2.36
value/fish ($)	9.10	18.30	16.05
Coho salmon			
avg wt (lb)	9.5	9.6	8.0
price/lb ($)	1.05	2.50	0.68
value/fish ($)	10.00	24.00	5.44

[1] Matkin and Fay (1980), courtesy of Morpac Inc.
[2] Alaska Dept. of Fish and Game 1988 summary, unpublished.
[3] Alaska Dept. of Fish and Game 1989 summary, unpublished.

Table 3. Distribution of field sampling effort (number of net observations) among "habitat zones," in the Copper River Delta, 1988.

	Copper River fishing district			
Zone	West 212-10	Central 212-20	East 212-30	Total
Channel	35	41	64	140
Surf	19	11	38	68
Nearshore	14	30	18	62
Offshore	9	46	2	57
Total	77	128	122	327

Salmon damage was evenly divided between marketable (0.88%) and not marketable (0.96%).

An attempt was made to examine differences in salmon damage by week, management unit, and habitat zone using Chi-square contingency tables (Zar 1974), but sample size proved inadequate in all cases.

In the field and dockside samples, northern sea lion predation on netted salmon was most prevalent in the spring sockeye fishery while harbor seal damage was most evident during the late summer coho salmon season (Table 4).

Northern sea lion predation on netted salmon was less frequent but more damaging than harbor seal predation. In most cases, sea lions either removed salmon from the net entirely or ate all but the head, leaving the fish unmarketable. Harbor seal damage was generally less destructive and resulted in complete loss of the salmon only if the body cavity was penetrated. Although not quantified in the field survey, the dockside survey revealed that 93 of the 113 (82.3%) sea lion-damaged salmon were unmarketable. Only 8 of the 79 (10.1%) harbor seal-damaged salmon were unmarketable, according to fishermen's reports. If only minimal damage was done to the head or caudal region of the fish, most fishermen would not separate them from the rest of their catch.

Pinnipeds scavenged primarily sockeye and coho salmon, although chinook salmon damage was also reported. To estimate the monetary losses associated with marine mammal damage, a $20 value per salmon was derived from 1988 average size and price figures for sockeye and coho salmon (Table 2). The estimated value of unsalvageable fish was extrapolated based on total landings and added to the reduced value of the salvageable salmon to estimate total losses to the fishery. Based on the 1988 field survey, the calculated overall loss from marine mammal damage was estimated at $248,637, or 0.7% of the total salmon harvest value in the Copper River and Bering River districts. The dockside survey indicated a monetary loss to the fishery of $243,475, or 0.68% of the 1988 harvest value.

Drift Net Damage Rates

Gear damage was attributed to marine mammals in 10 of the 327 (3.1%) field observations and 33 of the 67 (49.2%) dockside interviews in 1988. Northern sea lions accounted for the majority of damage to drift nets on the Copper River Delta in both samples (84% in field sample, 94% of dockside reports). Northern sea lion damage was limited to the spring sockeye salmon season.

Table 4. Weekly summary of observed fish and gillnet damage attributed to pinnipeds (SL = sea lion, HS = harbor seal) during field sampling on the Copper River Delta, 1988.

Week starting	Observed no. fish landed	No. (%) salmon damaged		No. (sq ft) gillnets damaged		
		SL	HS	SL	HS	Unknown
May 16	13	0	0	0	0	0
May 23	335	9 (2.7)	0	2 (24)	0	2 (2)
May 30	–	–	–	–	–	–
June 6	119	0	0	0	0	0
June 13	326	2 (0.6)	5 (1.5)	1 (5)	0	0
June 20	487	1 (0.2)	5 (1.0)	2 (11)	0	1 (3)
June 27	3	0	1 (33)	0	0	0
July 4	552	0	8 (1.5)	0	0	0
July 11	383	2 (0.5)	28 (7.3)	1 (6)	0	0
July 18	–	–	–	–	–	–
July 25	117	0	5 (4.3)	0	0	0
Aug 1	85	0	8 (9.4)	0	0	1 (4)
Aug 8	247	1 (0.4)	18 (7.3)	0	1 (2)	0
Aug 15	906	1 (0.1)	5 (0.6)	0	0	0
Aug 22	1,520	0	79 (5.2)	0	3 (7)	0
Aug 29	658	0	12 (1.8)	0	0	0
Sep 5	–	–	–	–	–	–
Sep 12	56	0	0	0	0	0
Total	5,807	16 (0.3)	174 (3.0)	6 (46)	4 (9)	4 (9)

All sea lion-caused net damage was observed in the field sample before 11 July while 79% of fishermen interviewed between 23 May and 4 June reported sea lion damage to their nets. Drift net damage by harbor seals was observed in the field sample only in August (Table 4). The extent of cetacean-caused damages was not quantified in this study but anecdotal reports suggest larger cetaceans such as killer, humpback, and minke whales that infrequently encounter offshore drift nets are able to break free unassisted, leaving holes proportional to their body size.

With the exception of juveniles, northern sea lions are apparently capable of breaking through drift nets without entangling, leaving holes ranging from 4 to 20 sq ft in size (mean = 7.7 sq ft; SD = 5.6). The largest hole observed was made by a sea lion that became momentarily entangled in the net, broke free, and swam repeatedly through the hole. Although both harbor seals and northern sea lions chewed on netted fish, sea lions also apparently tore salmon from the drift nets, removing pieces of mesh up to 30 cm in diameter in the process. Observed drift net damage resulting from entanglement or release of harbor seals, harbor porpoises, and sea otters was negligible. Drift net damage was not frequent enough to compare weekly rates.

Drift net damages by marine mammals were calculated as the area (sq ft) of net damaged per salmon landed. Using data obtained in the field sample, the calculated damage rate was 0.01 sq ft per salmon (55 sq ft of damage per 5,807 observed salmon). In the dockside sample, the calculated damage rate was 0.03 sq ft per salmon landed (294 sq ft damage per 10,539 fish landed). By extrapolating these figures to total landings and using an approximate repair cost of $5 per sq ft, marine mammal damages to Copper River Delta drift nets in 1988 ranged from $51,585 to $154,750. Because additional losses, related to reduced net efficiency and lost fishing time during repairs, could not be adequately estimated, this range represents a conservative minimum.

Table 5. Weekly summary of the frequency, number, and location of marine mammal species observed within 1 km of (but not harassing) active drift nets on the Copper River Delta during field sampling, 1988.

Week starting	Zone[1] C	Zone[1] S	Zone[1] N	Zone[1] O	HS Net obs	HS (No.)[2]	SL Net obs	SL (No.)	SO Net obs	SO (No.)	HP Net obs	HP (No.)	Other[3] Sp	Other[3] Net obs	Other[3] (No.)
May 16	4	0	0	1	3	(4)			1	(1)					
May 23	0	0	1	4			4	(5)							
May 30	–	–	–	–	–		–		–		–			–	
June 6	0	8	5	3	1	(1)	3	(8)	–		4	(5)	KW	1	(2)
June 13	1	1	2	1	3	(3)							MW	2	(2)
June 20	3	3	1	3	5	(5)	1	(1)	1	(1)			DP	1	(3)
June 27	1	2	0	0	1	(1)			2	(2)					
July 4	1	6	0	0	4	(4)	1	(1)	2	(2)					
July 11	0	2	5	6	4	(7)	2	(3)	1	(1)	1	(2)			
July 18	–	–	–	–	–		–		–		–				
July 25	26	4	1	0	1	(1)			8	(29)	1	(1)			
Aug 1	0	0	0	0											
Aug 8	0	0	1	1	1	(1)	–		1	(1)					
Aug 15	6	3	0	0	8	(8)	–		1	(1)					
Aug 22	11	4	0	0	9	(14)	–		1	(1)					
Aug 29	4	8	0	0	3	(3)			2	(9)					
Sep 5	–	–	–	–	–		–		–		–				
Sep 12	3	0	0	0	2	(2)			1	(1)					
Total	60	41	16	19	45	(54)	11	(18)	21	(49)	6	(8)		4	(7)

[1] Number of marine mammals seen in habitat zones: C = channel, S = surf, N = nearshore, O = offshore; – indicates week not sampled.

[2] Net obs = number of net observations in which mammals were seen within 1 km of net; No. = number of mammals seen weekly; HS = harbor seal, SL = northern sea lion, SO = sea otter, HP = harbor porpoise.

[3] Other = other marine mammal species seen; sp = species: KW = killer whale, DP = Dall's porpoise, MW = minke whale.

Marine Mammal Encounters

During the 1988 field sample, 136 marine mammals representing seven species were seen within 1 km of drift nets during 87 of the 327 (26.6%) observed sets (Table 5). Mammals in this category did not approach or show interest in the drift nets. Harbor seals and sea otters were most frequently observed, accounting for 54 (40%) and 49 (36%) of the mammals seen, respectively. Observed avoidance of drift nets by several sea otters, harbor seals, and harbor porpoises suggest individuals within these species are able to detect drift nets despite water turbidity.

In 1989, dockside sampling was eliminated and field sampling was limited to western portions of the study area. Therefore, changes in pinniped abundance, drift net harassment, and salmon damage on the Copper River Delta were not quantified. However, drift net fishermen reported a perceived reduction in the number of northern sea lions and resultant gear conflicts in 1989.

Net harassment. Pinnipeds working gear were observed or presumed to be scavenging salmon. Although sea otters were observed investigating drift nets on several occasions, their approach was accidental or inquisitive and appeared unassociated with predation of netted salmon. During the 1988 field survey, 154 marine mammals were seen working gear in 97 of the 327 (29.7%) observed sets. Harbor seals were most frequently involved in drift net harassment. A total of 118

Table 6. Weekly distribution of marine mammal-gillnet encounters seen during field sampling on the Copper River Delta, 1988.

Week starting	Working Gear[1] HS Net obs	(No.)	Working Gear[1] SL Net obs	(No.)	Observed mammal take: No. incidental kills	No. released[2]	No. intentional kills
May 16	0		0				
May 23	0		10	(23)		1 SL	
May 30	–		–		–	–	–
June 6	0		2	(2)		1 HP	
June 13	6	(7)	1	(4)			
June 20	5	(6)	3	(3)			
June 27	0		0				
July 4	3	(3)	1	(1)			
July 11	9	(14)	2	(2)			
July 18	–		–		–	–	–
July 25	3	(3)				5 SO	
Aug 1	1	(1)	0				
Aug 8	5	(7)	0				
Aug 15	10	(11)	1	(1)			
Aug 22	26	(56)	0		1 HS	2	HS
Aug 29	9	(10)	0				
Sep 5	–		–		–	–	–
Sep 12	0		0				
Total	77	(118)	20	(36)	1 HS	1 SL 1 HP 5 SO	2 HS

[1] Working gear: net obs = number of observations in which mammals were seen in or near drift nets: (No.) = number of mammals seen weekly; HS = harbor seal, SL = northern sea lion.

[2] No. released = number and species of mammals caught incidentally but released alive; HP = harbor porpoise, SO = sea otter, SL = northern sea lion.

were observed working the nets during 77 sets. Thirty-six northern sea lions were present in or near 20 of the observed sets, primarily in May and June (Table 6). Half the fishermen interviewed in the dockside survey reported northern sea lions worked their gear during the previous period. Fishermen who reported conflicts had been fishing throughout the Copper River Delta. Most conflicts occurred early in the spring. Harbor seals were reported to have worked the gear of 7 of the 67 (10.4%) fishermen interviewed, primarily in late June and July in central and eastern portions of the Copper River Delta (Fig. 5).

Field sampling revealed that geographic patterns of drift net harassment by marine mammals on the Copper River Delta differed among marine mammal species (Table 7). Harbor seal conflicts were most frequent in channel sets (69% of observations) and in the eastern portion of the study area. Interactions with northern sea lions were most frequent in surf and nearshore sets (42% and 39% of sets) in the central region of the study area (Fig. 6).

Marine mammal deterrents. Response of fishermen to marine mammals working drift nets varied according to the fishermen and marine mammal species involved (Table 8). Fishermen observed in the 1988 field sample attempted to deter the mammal from the net during 38 of 97 sets (39.2%) in which marine mammals were seen working the gear. Of the active deterrents

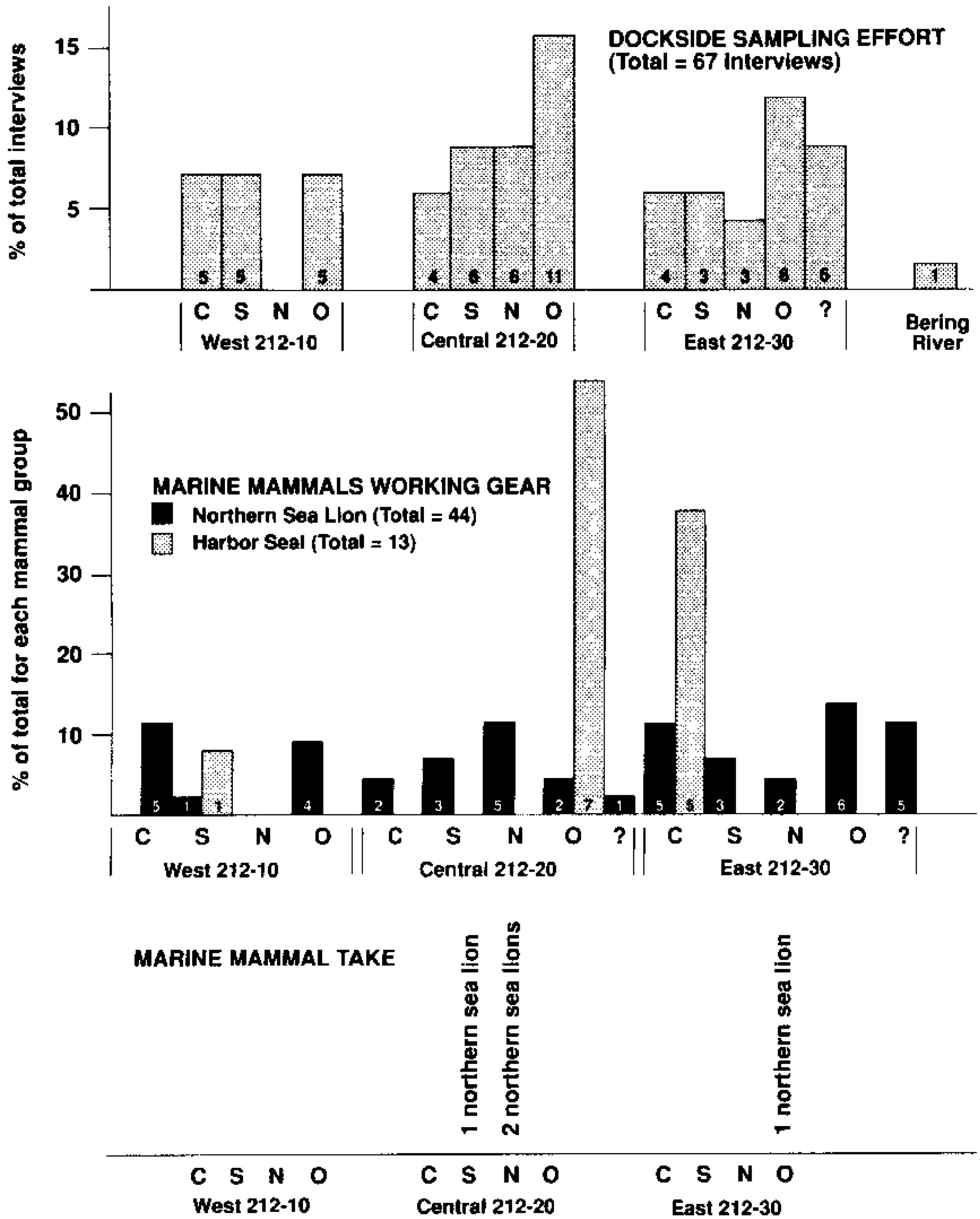

Figure 5. Top Panel: Habitat zone distribution of dockside sampling effort. Middle Panel: Habitat zone distribution of marine mammal encounters reported in dockside interviews, weeks starting May 23, May 30, June 13, July 11, and July 18. Bottom Panel: Habitat zone distribution of marine mammal take reported by fishermen in dockside interviews. (C = channel; S = surf; N = nearshore; O = offshore.)

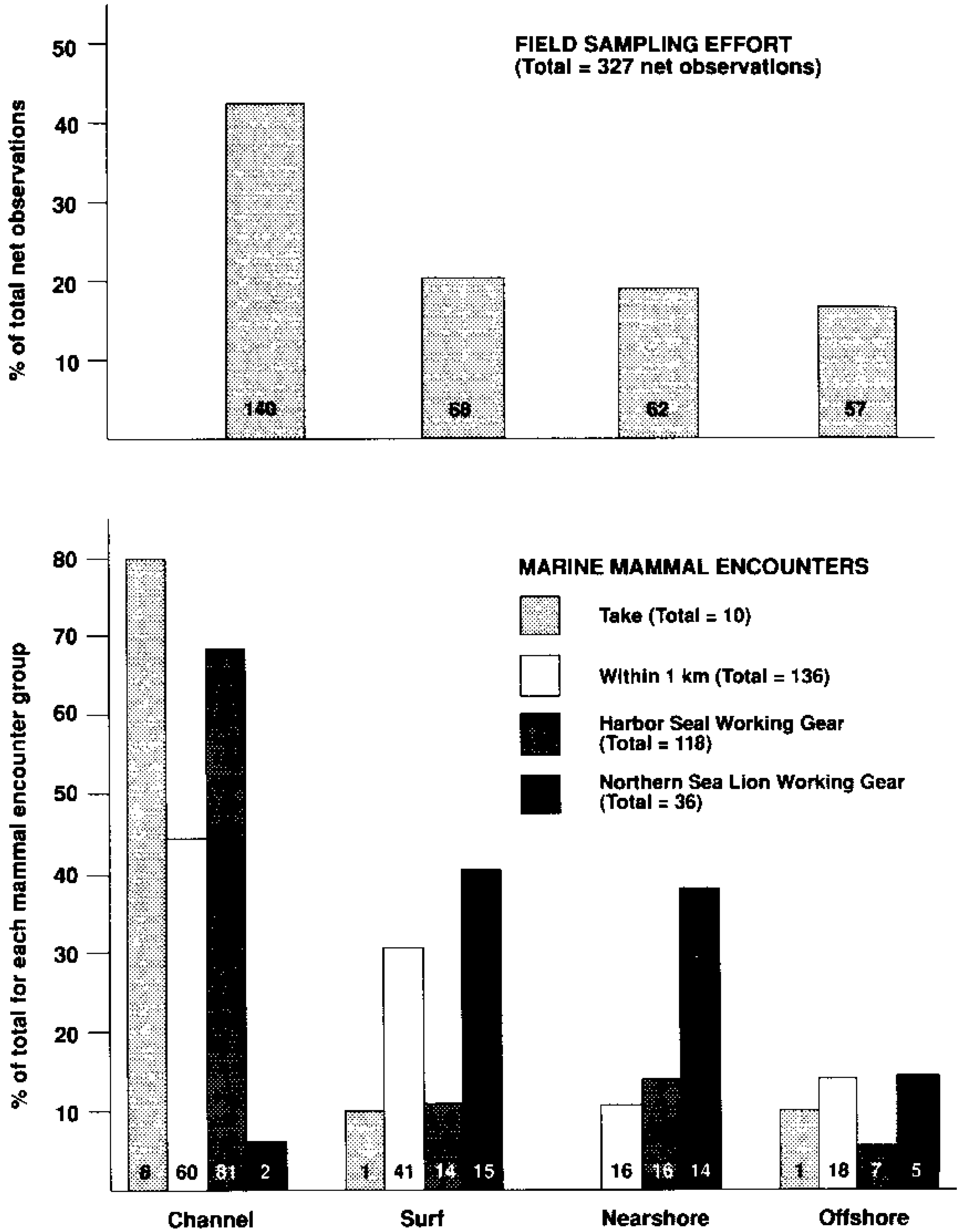

Figure 6. Top Panel: Habitat zone distribution of field sampling effort. Bottom Panel: Habitat zone distribution of marine mammal encounters observed in field sample, mid-May to mid-September 1988. Each "net observation" represents one setting, fishing, and retrieval of a net.

Table 7. Monthly fishing effort, sampling effort, and marine mammal take on the Copper River Delta, 1988.

	Fishing effort		Sampling effort				Marine mammal take	
			Field		Dockside			
	Permit-hrs	%	Permit-hrs	%	Permit-hrs	%	Field	Dockside
May	57,567	22.1	132	13.7	1,080	57.7	1 SL	4 SL
June	61,310	23.5	198	20.5	360	19.2	1 HP	
July	26,350	10.1	144	14.9	432	23.1	5 SO	
August	79,050	30.3	336	34.8			3 HS	
September	36,525	14.0	156	16.1				
Total	260,892		966		1,872		10	4

observed, the two most common forms were gunshots (18) and running gear (12). Shooting at harbor seals and northern sea lions to defend fishing gear was legal through 1989. Running gear is the practice of using the boat to chase mammals from the net after casting it adrift. Seal bombs (nonlethal underwater explosions) were used during six of the encounters and a combination of two or more deterrents was observed twice (Table 8).

The effectiveness of these techniques is difficult to assess without controlled experimentation. Deterrents were frequently used until the marine mammal departed, but the mammals also were observed to leave the gear when no deterrents were used. This limitation was recognized, and the relative effectiveness of deterrent strategies on harbor seals and northern sea lions was examined.

Overall, deterrents appeared to be more effective when used on harbor seals than on northern sea lions (86% and 67% successful, respectively). Although running gear was successful when used on both species, gunshots were twice as effective a deterrent of harbor seals as northern sea lions. Seal bombs were effective only when used to deter harbor seals. Deterrents were generally less effective when several mammals were working the gear (Table 9).

Of the 67 fishermen interviewed in the dockside survey, 37 (56%) reported that they actively attempted to deter marine mammals, primarily sea lions, from their gear. Gunshots were the most commonly reported deterrents (75% effective) followed by running the gear (64% effective), use of seal bombs (80% effective), and a combination of deterrents (75% effective). One fisherman reportedly hauled in his net and moved elsewhere to avoid northern sea lions (Table 8).

Marine mammal take. Ten cases of incidental or intentional marine mammal take were observed during 387 drift net sets observed in 1988 and 1989. Seven of the eight mammals caught incidentally were released or escaped unharmed (five sea otters, one harbor porpoise, one northern sea lion). The only incidental mortality observed was the drowning of a harbor seal pup that became entangled in a drift net set at night in shallow water. During field sampling, two harbor seals were shot and killed directly by fishermen defending their gear and catch (Table 6).

Although marine mammal take was too infrequent in the field sample to determine accurate spatial and temporal rates, several trends were noted. Channel sets were responsible for eight of the ten marine mammal takes, including all sea otters and harbor seals. The northern sea lion capture was in the surf zone and the harbor porpoise capture occurred in offshore waters. All sea otter captures occurred in the western management units while all harbor seal captures occurred in the eastern management units.

Fishermen reported marine mammal takes in four of the 67 interviews conducted in 1988 (Table 7). All four mammals were northern sea lions—one was caught and drowned in the net and three were shot and believed killed in the course of defending gear and catch. All four en-

Table 8. Frequency of deterrent use against marine mammals by drift net fishermen, as reported by fishermen (dockside sample) and observed (field sample) on the Copper River Delta, 1988.

Sample	Mammals[1] reported in or near nets	Deterrent[2] total No. (%)	Deterrent type Gunshot	Ran gear	Seal bomb	Combination	Moved net[3]
Field	97	38 (39.2)	18	12	6	2	0
Dockside	40	37 (92.5)	16	11	5	4	1

[1] Number of reports or observations in which marine mammals approached or harassed an active drift net.
[2] Number of reports or observations in which fisherman deterred marine mammals approaching their net.
[3] Moved net out of area.

counters were in May when northern sea lions were most abundant on the delta.

Other anecdotal reports of marine mammal interactions were received periodically in 1988. One report recounted the capture of a young humpback whale in an offshore set. The animal escaped unharmed when the drift net was stretched with the assistance of a second vessel. During the first two fishing periods of 1988 several killer whales were seen in nearshore waters of the Copper River Delta. One fisherman reported a killer whale ran through his gear, damaging approximately 18 m of drift net.

Beached Carcass Survey

Surveys conducted during this study found no evidence of fresh marine mammal carcasses before the 1988 and 1989 salmon season. The 1988 pre-season ground survey of two western beaches uncovered only partial skeletal remains of harbor seals and sea otters. The 1989 pre-season aerial survey of the barrier islands from Softuk to Hook Point failed to locate any marine mammal carcasses.

The barrier beaches of the Copper River Delta were aerially surveyed 36 times during the 1988 and 1989 salmon seasons to locate marine mammal carcasses (Table 10). A total of 91 carcasses representing five species of marine mammals were located during 1988 beach surveys. Seven carcasses could not be reached and an additional nine beached carcasses were reported to personnel but were not available for examination. Of the 100 carcasses examined or reported in 1988, 41 were northern sea lions, 27 were sea otters, 19 were harbor seals, 12 were harbor porpoises, and one was an elephant seal (Table 11).

In 1989, only 50 carcasses, or half the 1988 total, were found beached on the Copper River Delta. Although the number for all species was reduced in 1989, the most significant reduction was in the number of pinnipeds. One-third the 1988 number of northern sea lion and harbor seal carcasses were found in 1989 (Table 11). The numbers of beached harbor porpoises and sea otters found in 1989 were also lower than the 1988 totals (Table 10). Remains of one Dall's porpoise were found in 1989. Of 50 carcasses found in 1989, 44 were available for necropsy.

When possible, the sex of each carcass was determined and evidence of pregnancy was recorded. The sex ratio of northern sea lion and harbor seal carcasses was close to 1:1 while sea otter and harbor porpoise carcasses were predominantly male (Table 11). While fetuses were recovered from seven of 17 (41.2%) adult female northern sea lions and three of seven (42.8%) adult female harbor seals (Table 10) in 1988, no fetuses were found in 1989.

Carcasses were found throughout the summer (Fig. 7) on all major barrier islands in the study area (Fig. 8). A seasonal pattern of carcass deposition is evident for different species and reflects their relative abundance in the area. Most sea otter carcasses were recovered from Egg Island and Strawberry Beach, primarily in late summer. Northern sea lion and harbor seal carcasses were found throughout the study area in both years, primarily in May through July (Fig. 7).

When possible, the cause of each marine mammal death was determined. Limited necropsy time, decomposition, and scavenging of the carcasses made this determination impossible for 75 of the 128 carcasses (58.6%) examined in 1988

Table 9. Effectiveness of techniques used to deter harbor seals and sea lions from salmon drift nets on the Copper River Delta, as observed in the 1988 field sample (S = successful, U = Unsuccessful).

No. mammals seen in or near nets	Gunshot		Running gear		Seal bomb		Combination		Total	
	S	U	S	U	S	U	S	U	S	U
Sea lions										
1	1	1	3	0	0	1	0	0	4	2
2–4	0	1	1	0	0	0	0	0	1	1
≥5	0	0	1	0	0	0	0	0	1	0
Total	1	2	5	0	0	1	0	0	6	3
Harbor seals										
1	8	0	6	0	0	0	2	0	16	0
2–4	2	3	1	0	5	0	0	0	8	3
≥5	0	2	0	0	0	0	0	0	0	2
Total	10	5	7	0	5	0	2	0	24	5

and 1989 (Table 11). Twelve of the carcasses examined in 1988 (ten northern sea lions and two sea otters) are believed to have died from gunshot wounds. Twelve other carcasses (six northern sea lions and six harbor seals) bore suspected gunshot injuries. Of the 44 carcasses examined in 1989, five northern sea lions and two harbor seals bore definite or suspected gunshot wounds (Table 11).

Drowning was believed to be the cause of death of six mammals in the 1988 survey (one northern sea lion, two sea otters, and three harbor porpoises). Severe head injury is believed to have caused the death of eight of the 38 sea otters (21%) examined in 1988 and 1989. Nine mammals (7%) of the 1988 and 1989 surveys are believed to have died of natural causes, including malnutrition or gastric enteritis in six sea otters and two harbor seals, and complicated parturition in one harbor seal (Table 11).

The skulls of six sea otters and four northern sea lions whose cause of death could not be determined in the field were collected for further examination. One of the sea otters was found to have a fractured skull and three northern sea lions had been shot in the head. One of these sea lions, a large bull, died from buckshot wounds to the head but also had bird shot pellets imbedded in its frontal and nasal bones. The age of the wound suggests this animal had previously encountered humans and survived the earlier gunshot wound.

Four sea otter carcasses whose cause of death could not be determined in the field were sent whole to pathologists for necropsy. All exhibited signs of gastric enteritis, a non-specific terminal symptom found frequently in emaciated sea otters.

The stomach contents of beached marine mammals were not systematically examined. The stomachs of several fresh carcasses were grossly examined and primary prey items were recorded. Sockeye salmon remains were found in five northern sea lion stomachs in 1988 (two adult males, two pregnant and one subadult females). Recovery of nearly whole, undigested salmon from two animals suggests they were feeding immediately prior to death from gunshot wounds. The only identifiable remains recovered from harbor seal stomachs were complete and partially digested eulachon (three animals).

The deployment of marked buoys and tagged carcasses in 1988 was largely unsuccessful at demonstrating carcass drift and deposition patterns in the study area. Only one buoy was resighted. It was found in Bettles Bay in southwestern Prince William Sound, approximately 193 km west of its release site off Kokinhenik Island (Fig. 3). A larger sample is required to determine deposition rates and drift patterns.

Table 10. Summary of beach surveys conducted on the Copper River Delta May–September, 1988 and 1989.

	No. of carcasses found[1]						Location[2]							Condition[3]				
Date	No. (r)	SL	HS	HP	SO	+	SB	E	CS	G	K	EK	S	F	P	D	U	R
1988																		
5-19	7	2	5	0	0	0	0	2	1	0	1	1	2	5	1	1	0	0
5-25	9	4	5	0	0	0	1	0	2	2	1	2	1	4	4	1	0	0
6-01	13 (1)	11	1 (1)	0	1	0	2	1	0	5	1	4	0	5	4	4	0	0
6-08	13	8	0	4	1	0	3	2	2	2	2	1	1	1	6	6	0	0
6-15	9 (3)	7 (3)	1	0	1	0	6	3	2	1	0	0	0	1	0	8	3	0
6-22	1 (1)	1	0	0	0	(1)	1	1	0	0	0	0	0	0	0	1	0	1
6-30	1 (1)	1	0	(1)	0	0	1	0	0	1	0	0	0	0	0	1	0	1
7-06	4	0	2	1	1	0	0	2	0	0	0	1	1	1	1	2	0	0
7-13	2	2	0	0	0	0	0	1	0	1	0	0	0	0	0	1	0	1
7-20	1	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0
7-27	3	2	0	1	0	0	1	1	0	0	0	1	0	2	0	0	0	1
8-04	2	0	2	0	0	0	0	2	0	0	0	0	0	0	1	0	0	1
8-14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8-19	4	0	0	2	2	0	1	1	0	1	0	1	0	2	2	0	0	0
8-27	1	0	0	1	0	0	0	0	0	0	0	1	0	1	0	0	0	0
9-06	10 (10)	0	1 (1)	1 (1)	8 (8)	0	19	0	0	0	0	0	1	2	10	6	0	2
9-16	40	0	0	0	4	0	4	0	0	0	0	0	0	3	0	1	0	0
Total	84 (16)																	
1989																		
5-13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5-17	1	0	0	0	1	0	1	0	0	0	0	0	0	0	1	0	0	0
5-25	2	0	1	1	0	0	2	0	0	0	0	0	0	0	0	2	0	0
6-02	2 (1)	(1)	0	0	2	0	1	2	0	0	0	0	0	1	1	0	0	1
6-07	4	2	1	0	1	0	1	1	0	1	0	0	1	1	0	2	1	0
6-14	1	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0
6-21	1	0	1	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0
6-28	9	0	3	3	3	0	0	6	1	0	1	0	1	4	0	3	1	1
7-05	6 (1)	1	0	1	3 (1)	1	5	1	1	0	0	0	0	1	1	0	2	3
7-12	4	2	1	1	0	0	0	2	0	0	0	2	0	1	1	1	0	1
7-19	2 (1)	0	1	0	1 (1)	0	0	2	0	0	1	0	0	1	0	0	0	2
7-25	1	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0
8-03	2	0	1	1	0	0	2	0	0	0	0	0	0	0	1	0	0	1
8-09	4	0	0	0	4	0	3	1	0	0	0	0	0	1	2	0	0	1
8-16	2 (1)	1 (1)	0	0	1	0	1	1	0	1	0	0	0	0	1	0	1	1
8-23	1 (1)	0	0	0	1 (1)	0	1	1	0	0	0	0	0	0	1	0	1	0
8-29	1 (1)	0	0	0	1 (1)	0	1	1	0	0	0	0	0	0	1	0	0	1
9-17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9-29	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0	1	0	0
Total	44 (6)																	

[1]No. of carcasses examined. (r) = carcasses reported but not examined; SL = northern sea lion, HS = harbor seal, HP = harbor porpoise, SO = sea otter, + = elephant seal in 1988, Dall's porpoise in 1989.

[2]SB = Strawberry Beach, E = Egg I., CS = Copper Sands, G = Grass I., K = Kokinhenik, EK = East Kokinhenik, S = Softuk.

[3]F = fresh, P = partially decomposed, D = decomposed or scavenged, U = unsalvageable, R = rotten.

Table 11. Summary of marine mammal carcasses found or examined during beach surveys on the Copper River Delta May–September, 1988 and 1989.

Animal[1]			Sex[2]			Estimated age class[3]				Cause of death[4]					
Sp	No.	(r)	M	F (pg)	U	Y	S	A	U	U	G	S	D	T	N
1988															
SL	38	(3)	19	17 (7)	2	1M	9M,5F,1U	9M,12F	1	21	10	6	1	0	0
HS	17	(2)	7	7 (3)	3	1M,1F	3F,1U	6M,3F	2	9	0	6	0	0	2
SO	19	(8)	16	2	1	7M	3M,1F,1U	6M,1F	0	10	2	0	2	3	2
HP	10	(2)	6	1	3	2M	0	4M,1F	3	7	0	0	3	0	0
ES		(1)	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	84	(16)													
1989															
SL	8	(2)	3	4	1		1M,1U	2M,2F	0	3	4	1	0	0	0
HS	9		5	3	1	1M,1F,1U	2F	3M	1	6	1	1	0	0	1
SO	19	(4)	12	7	0	2M,2F	6M,1F	4M,2F,2U	0	10	0	0	0	5	4
HP	7		2	2	3			2M,2F,1U	2	7	0	0	0	0	0
DP	1				1				1	1	0	0	0	0	0
Total	44	(6)													

[1] Number necropsied, (r) = number seen or reported but not necropsied), SL = northern sea lion, HS = harbor seal, SO = sea otter, HP = harbor porpoise, ES = elephant seal, DP = Dall's porpoise.
[2] M = male, F = female, U = undetermined, (pg) = number of pregnant females.
[3] Y = young of the year, S = subadult, A = adult, U = undetermined.
[4] U = undetermined, G = definite gunshot, S = suspected gunshot, D = drowned, T = skull trauma, N = natural (malnutrition or complicated parturition).

The only other indication of duration and direction of marine mammal carcass drift came from the recovery of a drift net-entangled northern sea lion carcass which fit the description of one reported in the dockside survey. The animal, reportedly drowned near Grass Island on 15 June 1988, was reduced to hide and skeleton when found beached on Egg Island approximately 30 km west on 24 May 1988. A noticeable deterioration in the condition of beached sea lion carcasses was seen with time, suggesting many found in later surveys had drifted a long time prior to washing ashore.

Once beached, marine mammal carcasses decomposed or were scavenged at different rates, dependent on the species and condition when beached. Bald eagles are the primary scavengers on the barrier islands although brown bears, fox, and coyotes are also present. For large harbor seal and northern sea lion carcasses, scavenge rate was largely dependent on the level of decomposition when beached. Those that washed ashore soon after death remained intact the longest. Several sea lions examined in May were still evident in September. Pups and larger specimens that washed ashore in a partially decomposed state were more easily consumed and often were completely removed within one week. Porpoises, lacking the tough hide of the pinnipeds, were generally reduced to skeletal remains within 1-2 days. Sea otter carcasses apparently are not preferred carrion for eagles; several remained largely intact on the beaches for weeks.

DISCUSSION

Difficulties in Conflict Assessment

The cumulative results of field, dockside, and carcass surveys provide an overview of current marine mammal interactions with the salmon drift net fishery on the Copper River Delta. How-

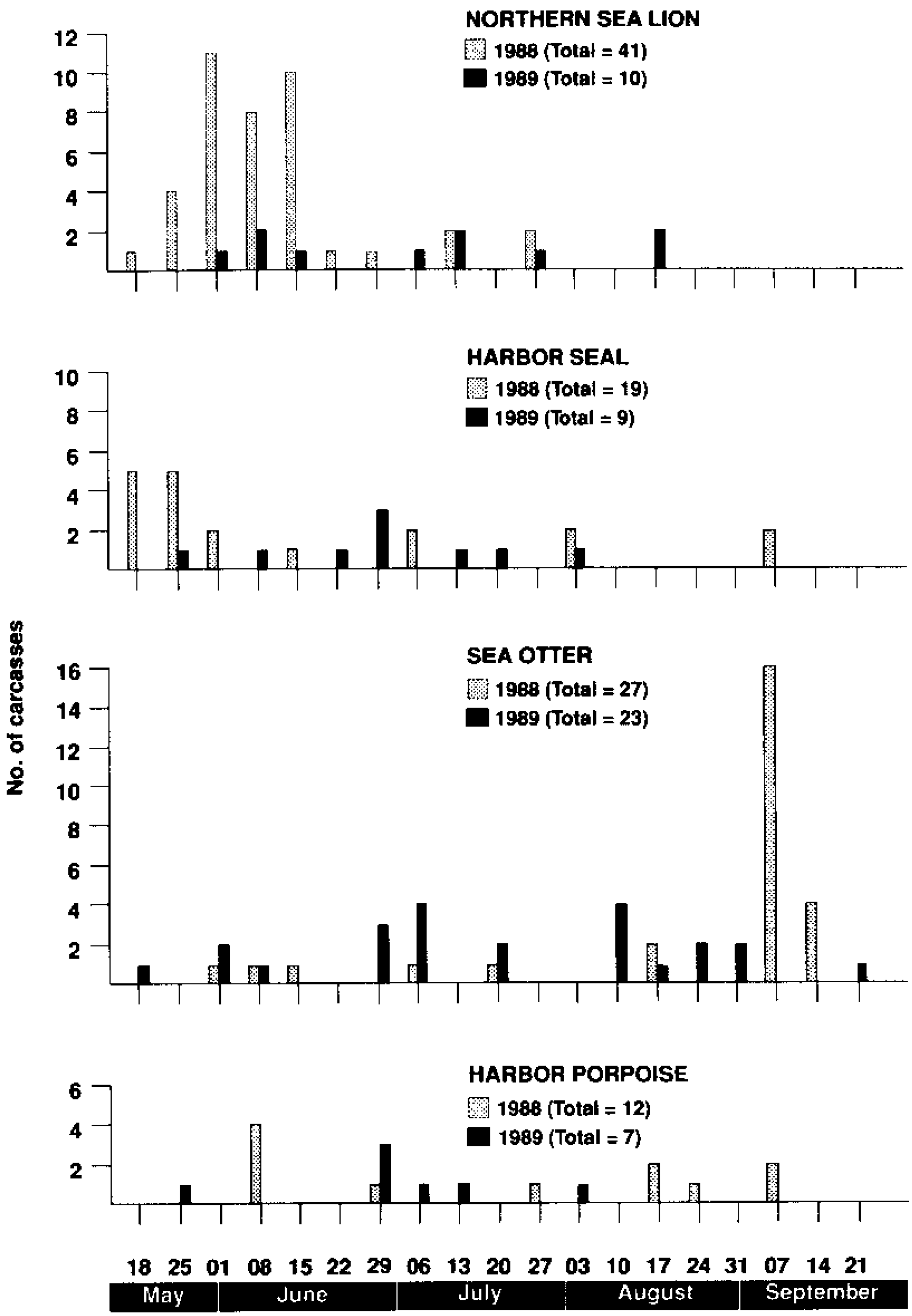

Figure 7. Seasonal summary of marine mammal carcasses found during weekly aerial surveys of beaches from Hook Point to Softuk, Copper River Delta, 1988 and 1989.

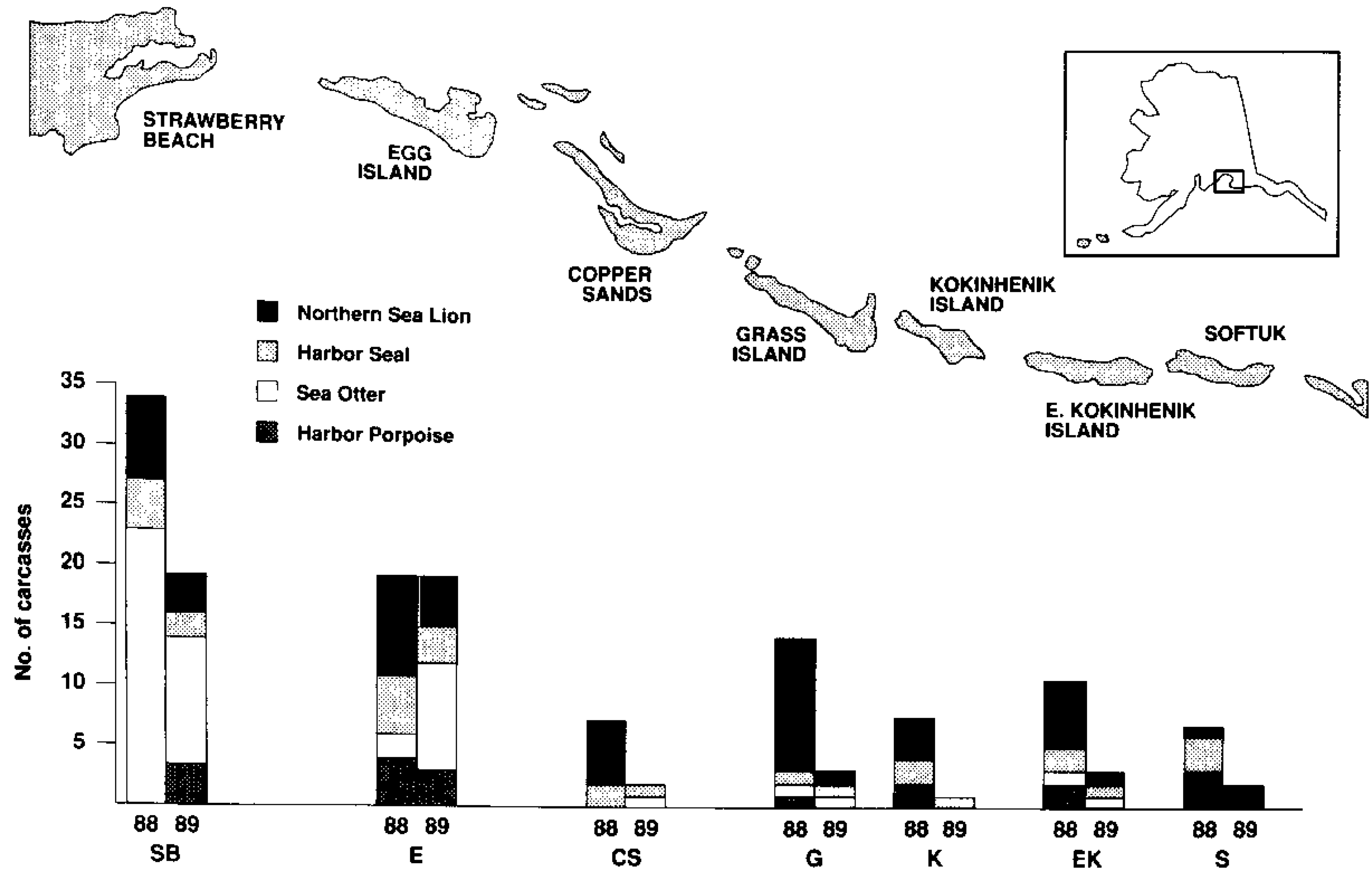

Figure 8. Frequency and distribution of marine mammal carcasses observed or necropsied during aerial surveys of beaches on the Copper River Delta, May to September 1988 and 1989 (1988 total = 100; 1989 total = 50).

ever, due to limited sample size and biases, even the cumulative results suggest only trends and patterns and do not document fishery-wide take estimates. A sample size much greater than that reported here—less than 1% of fishing effort—is required before the results can be realistically extrapolated to the fishery.

The use of active fishing vessels as observer platforms and the inclusion of dockside reports introduced a number of biases into the surveys. Field observations were not random or independent events, and sampling effort could not be effectively stratified. Therefore, the data gathered could not be subjected to rigorous statistical testing and quantitative interpretations. The presence of an observer on board vessels may also have altered the behavioral response of fishermen to marine mammal conflicts. There is also an inherent potential for reporter bias in all dockside sampling. Interviewed fishermen may tend to overestimate salmon and gear damage and underestimate marine mammal mortality due to the political consequences of their reports. I think both biases were minimal in the 1988 surveys but anticipate they will increase with changes in the legal status of northern sea lions.

Marine mammal conflicts have a clumped distribution; fishermen do not experience them with the same frequency throughout the Copper River Delta. Those who fish in channels rarely experience northern sea lion problems or catch porpoises while those who fish outside waters rarely encounter sea otters. Because conflicts are regional, it is unrealistic to extrapolate observed rates of conflicts across the fishery without an adequately large sample from each affected area.

Comparison of Conflicts, 1978 and 1988

Marine mammal damage. As reported for 1978 (Matkin and Fay 1980), pinnipeds were responsible for the vast majority of marine mammal-caused damages experienced by the fishery in 1988. The rate of marine mammal predation on netted salmon calculated in the present study ranged from 1.8% to 3.2% of total salmon landings based on the dockside and field surveys, respectively. This suggests a decrease in damaged salmon from the 1978 season estimated loss of 2.52 to 3.88% of total salmon landings on the Copper River Delta and Prince William Sound (Matkin and Fay 1980). The 1988 estimated $250,000 loss to the fishery from marine mammal damage is comparable to 1978 losses only because the market value of salmon doubled in 1988.

The 1988 estimate of marine mammal-caused drift net damage differed significantly between the dockside and field samples. Fishermen reported a damage rate (0.03 sq ft per salmon) three times higher than reported by field observers (0.01 sq ft per fish). This likely reflects a seasonal bias in the dockside sample toward spring when northern sea lion damage was more prevalent on the Copper River Delta. Both samples suggest a drastic reduction in the extent of drift net damage by marine mammals from the 1978 estimate of 4.4 sq ft per salmon landed, reported by Matkin and Fay (1980).

Although a comparable field sample is not available for 1989, anecdotal reports from Copper River drift net fishermen indicate much less drift net damage occurred in 1989 than in previous years. Most attributed this to the relative lack of northern sea lions in the fishing area.

Marine mammal take. The number of marine mammals killed intentionally and incidentally in the course of the 1988 salmon drift net season cannot be determined with certainty due to the limited size and scope of the samples. However, to facilitate comparison with existing documentation, sample results and mortality rate estimates were compared to those reported in 1978 (Matkin and Fay 1980).

Despite sampling differences and statistical limitations, results of the 1978 and 1988 studies provide an index of conflict trends on the Copper River Delta. Matkin and Fay (1980) relied on dockside interviews for reports of marine mammal conflicts. They found the distribution of marine mammal conflicts on the Copper River Delta was clumped, but the distribution of total marine mammal take rates was extrapolated evenly across the fishery. Similar geographic and seasonal patterns of marine mammal conflicts were found in 1988 field and dockside samples. Because take rates were not uniform throughout the delta, straight ratio extrapolation of mortality rate estimates to the fishery was deemed inappropriate. Therefore, conflict trends are examined by comparing unextrapolated rates from 1978 and 1988 (Table 12).

Pinnipeds: The response of fishermen to predation and drift net harassment by pinnipeds varied from indifferent tolerance to active defense of their gear and catch. Because active gear defense legally could include the use of firearms through 1989, a number of pinnipeds were intentionally killed in the course of the 1978 and 1988 drift net fishing activities. Incidental pinniped mortality also occurred in drift gillnets as a result of entanglement and removal from the nets.

Pinniped mortality rate reported in dockside surveys was significantly reduced ($P < 0.001$) between 1978 and 1988 (Table 12). During the six week salmon season of 1978, Matkin and Fay (1980) received reports from Copper River Delta drift net fishermen of 36 intentional (15 harbor seals, 21 northern sea lions) and nine incidental (all harbor seals) pinniped fatalities. In the 15 weeks surveyed in 1988, five intentional (three northern sea lions, two harbor seals) and two incidental (one harbor seal, one northern sea lion) pinniped deaths were reported in the field and dockside samples (Fig. 9).

Comparable sampling was not conducted in 1989 but results of the carcass survey suggest a further reduction in drift net-related pinniped mortality on the Copper River Delta. Although many variables influence carcass deposition rates on the delta, the most obvious and significant factor is the number of mammals dying in the area. The drastic difference in the number of pinniped carcasses found on the delta during the 1988 and 1989 salmon drift net seasons implies mortality, particularly drift net-related mortality, may vary significantly between years in the area.

Sea otters: Incidental sea otter take increased from four reported entanglements in 1978 to five observed entanglements in 1988. In both years, multiple sea otter entanglements occurred in drift nets on the Copper River Delta. In 1978, the four reported sea otter entanglements occurred in two sets. The five sea otters entangled during the 1988 field observations were seen in two net observations. In both years, entangled sea otters were released unharmed from drift nets.

Harbor porpoises: The number of harbor porpoises incidentally taken in Copper River Delta drift nets declined from seven in 1978 to one in 1988 samples. Of the seven harbor porpoises incidentally entangled in 1978, three were released unharmed and four died before release from the net (Matkin and Fay 1980). In 1988, no incidental porpoise entanglements were reported in the dockside sample. Harbor porpoise mortality rate estimates did not differ significantly

Table 12. Comparison of observer effort and marine mammal take observed (field sample) and reported (dockside sample) on the Copper River Delta, 1978 and 1988.

	1978[1]	1988	
	Dockside	Field	Dockside
No. weeks sampled	6	15	5
No. boats (sets) sampled	179	327	67
No. fish landed in sample	39,752	5,807	10,539
Mammal take[2]			
No. captured and released			
SL	0	1	0
HS	3	0	0
SO	4	5	0
HP	3	1	0
Total	10	7	0
Incidental kills			
SL	0	0	1
HS	9	1	0
SO	0	0	0
HP	4	0	0
Total	13	1	1
Intentional kills			
SL	21	0	3
HS	15	2	0
SO	0	0	0
HP	0	0	0
Total	36	2	3

[1] Matkin (1980).
[2] Species: SL = northern sea lion, HS = harbor seal, SO = sea otter, HP = harbor porpoise.

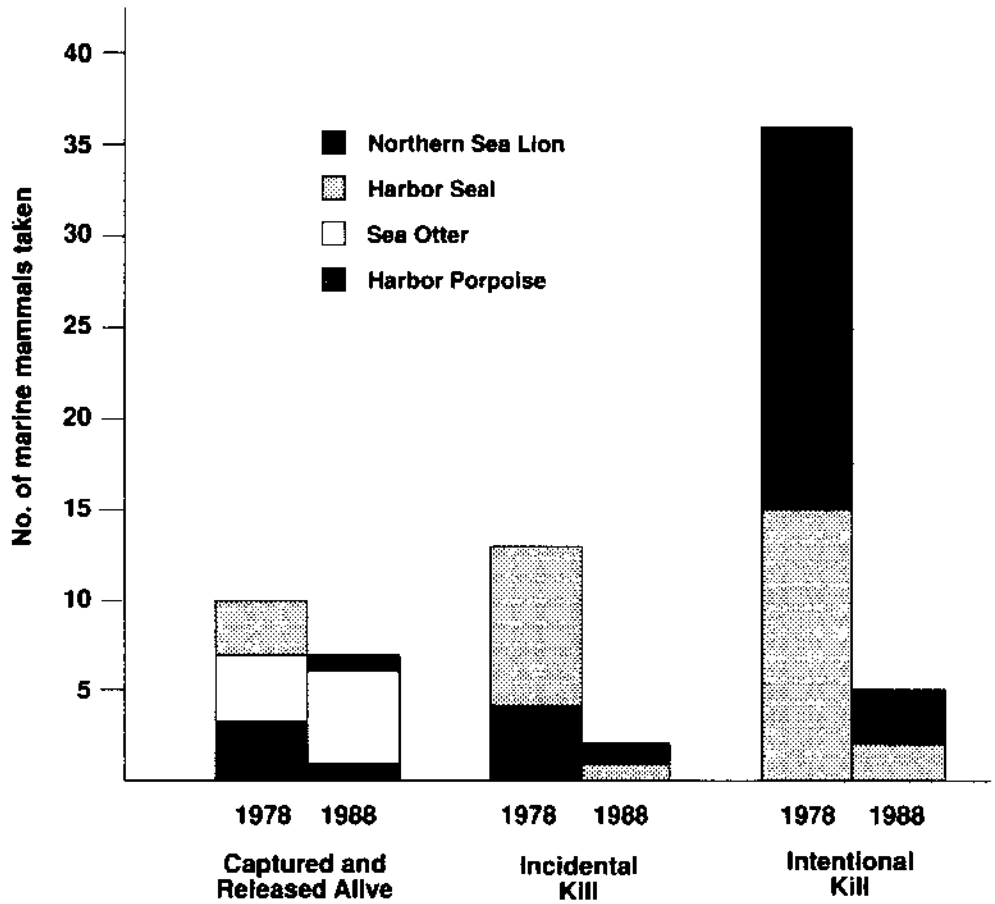

Figure 9. Marine mammal take reported during the six-week drift net season in 1978 (dockside reports, Matkin 1980), and the 15-week drift net season in 1988 (combined dockside and observer report on the Copper River Delta.

(0.10<P<0.20) between 1978 and 1988 (Table 13). One harbor porpoise observed incidentally entangled during the field sample was released unharmed. No intentional killing of harbor porpoises by salmon drift net fishermen occurred on the Copper River Delta in either year.

Deterrents

Approximately 70% of the drift net fishermen interviewed or observed attempted to deter marine mammals from their gear; 75% of those thought they were successful. Gunshots were most frequently used but were not as effective a deterrent as running the gear or using seal bombs. Deterrent effectiveness was dependent on the species involved and the number of other vessels fishing in the area. As reported in 1978 (Matkin and Fay 1980), it was easier to force a marine mammal to leave one drift net if another was close by for it to move to. The majority of fishermen using guns as deterrents reported their intention was to discourage, not kill, the mammal. Most believed their success at hitting a marine mammal was extremely low due to sea action, the distance of the target from the boat, and the mammal's avoidance behavior.

Other nonlethal deterrents that were available but not observed or reported during the 1988 season include 12 gauge cracker shells, rubber bullets, and acoustic devices.

Table 13. Comparison of marine mammal mortality rates reported in dockside interviews in 1978 (Matkin 1980) and 1988 on the Copper River Delta.

	Reported no. of deaths			Proportion[1]	
	Incidental	Intentional	Combination	with deaths	Significance[2]
Pinnipeds	9			$\hat{p}_1 = 0.050$	no
1978	1			$\hat{p}_2 = 0.015$	Z = 0.124
1988				$\hat{p} = 0.041$	($P > 0.25$)
				$\hat{q} = 0.959$	
1978		36		$\hat{p}_1 = 0.201$	yes
1988		3		$\hat{p}_2 = 0.045$	Z = 3.00
				$\hat{p} = 0.159$	($P < 0.005$)
				$\hat{q} = 0.841$	
1978			45	$\hat{p}_1 = 0.251$	yes
1988			4	$\hat{p}_2 = 0.060$	Z = 3.35
				$\hat{p} = 0.200$	($P < 0.001$)
				$\hat{q} = 0.800$	
Harbor porpoise					
1978	4			$\hat{p}_1 = 0.022$	no
1988	0			$\hat{p}_2 = 0$	Z = 1.23
				$\hat{p} = 0.016$	($0.10 < P < 0.20$)
				$\hat{q} = 0.984$	
Combined mortality for all marine mammals					
1978			49	$\hat{p}_1 = 0.274$	yes
1988			4	$\hat{p}_2 = 0.060$	Z = 3.63
				$\hat{p} = 0.215$	($P < 0.001$)
				$\hat{q} = 0.785$	

[1] Proportion based on number of interviews: 1978 $n_1 = 179$ (Matkin 1980), 1988 $n_2 = 67$, total $n = 246$.
[2] Where:

$$Z = \frac{\hat{p}_1 - \hat{p}_2}{\sqrt{\frac{\hat{p}\hat{q}}{n_1} + \frac{\hat{p}\hat{q}}{n_2}}}$$

was used to test the null hypothesis: the same proportion of deaths were reported in 1978 and 1988 dockside interviews.

Species-Specific Conflicts

Northern sea lions. Despite declines in northern sea lion numbers in western Alaska (Loughlin et al. 1984, Merrick et al. 1987), the number of sea lions on rookeries and haul-outs in southeastern Alaska and the eastern Gulf of Alaska have remained stable or increased (Pitcher and Vania 1973, Merrick et al. 1987). Included in this area are a rookery (Seal Rocks) and a haul-out (Cape St. Elias) adjacent to the Copper River Delta (Pitcher and Vania 1973) (Fig. 1). The relative stability of these sites suggests local northern sea lion numbers have not declined appreciably despite a 40 year history of conflicts with the Copper River salmon fishery. It also suggests that conflicts likely will continue between the fishery and the locally, seasonally abundant predator.

Results from the 1978 (Matkin and Fay 1980) and 1988 studies indicate northern sea lion presence and predation of netted fish on the Copper River Delta were predominantly a spring phenomenon, coinciding with the sockeye salmon run. This seasonality coincides with the onset of northern sea lion breeding and pupping activities on adjacent rookeries. In May, adult females are near parturition and adult males approach the breeding season during which they fast for 40 days and maintain territories (Sandegren 1970). During this period, sea lions are subject to their highest energetic demands (Keyes 1968) and respond by increasing their consumption to meet the 13% rise in energy needs (Ashwell-Erickson 1981).

It is unclear whether northern sea lions are attracted to the delta from adjacent rookeries and haul-outs by the salmon run or by the spring run of eulachon in the Copper River upon which they also feed. Once in the area, however, they encounter a high concentration of drift nets and netted sockeye salmon. As opportunistic feeders, northern sea lions forage on the most readily available sources of high-energy food, including the oily eulachon and sockeye salmon.

An apparent change in this pattern was qualitatively noted in 1989. Anecdotal reports suggest northern sea lion presence on the delta was greatly reduced despite documented abundance on Seal Rocks and Cape St. Elias. The reasons for their absence from the fishing districts are unclear but may involve changes in prey distribution. Large schools of herring or capelin were seen by pilots flying near Cape St. Elias, and spawning of eulachon in the Copper River was apparently later than normal in 1989. As opportunists, northern sea lions likely would prey on large schools of fish available near their haul-outs rather than swimming further into the Copper River Delta to feed.

The reduced number of northern sea lions on the delta in 1989 apparently resulted in a reduction of conflicts with Copper River drift net fishermen. This undoubtedly affected local northern sea lion mortality, as seen in the reduced number of beached and gunshot carcasses found. A change in the number, attitude, and behavior of drift net fishermen involved in sea lion conflicts likely contributed to the reduced northern sea lion mortality observed on the delta in 1989.

An increased tolerance of sea lions by Copper River drift net fishermen is evident, particularly when compared to attitudes documented in 1978 by Matkin and Fay (1980). Many fishermen who previously had shot at northern sea lions in defense of their gear and catch did not carry guns onto the delta or used nonlethal deterrents in 1988 and 1989. This reflects, in part, an awareness of the recently publicized decline in sea lion numbers and concern for the legal, political, and financial ramifications of shooting northern sea lions. The voluntary support of this study by Copper River fishermen further attests to their willingness to document existing conflicts and seek viable mitigation measures.

Harbor seals. Although harbor seals were more frequent scavengers of netted salmon, they generally caused less damage to both the drift net and salmon than did northern sea lions. Consequently, drift net fishermen were more tolerant of harbor seals near their nets than northern sea lions.

The seasonal pattern of salmon scavenging by harbor seals coincided with their presence and use of sandbars in the Copper River for pupping. In early summer adult females in the area are subject to increased energetic demands of parturition and lactation (Ashwell-Erickson 1981), while all adults are stressed in mid-summer by the energetic demands of breeding and molting (Pitcher 1977). Although adult harbor seals may scavenge netted sockeye salmon at this time, they probably also feed on the eulachon run in the Copper River, as suggested by prey remains recovered from harbor seal carcasses examined in this study and from the Columbia River in Washington (Beach et al. 1985). Harbor seals observed scavenging coho salmon from drift nets in August and September apparently were recently weaned pups that encountered drift nets in the sheltered waters of the delta.

Harbor seal conflicts with the spring sockeye salmon fishery appear to be less frequent in 1988 than in 1978. Only minor harbor seal predation and mortality were reported by fishermen in the spring of 1988 while harbor seals comprised one-third of the incidental and intentional kill reported in the spring of 1978 (Matkin and Fay 1980). Harbor seal scavenging and mortality were predominantly associated with the late-summer coho season in the 1988 survey. This likely reflects the late-summer abundance of inexperienced pups in the area.

Sea otters. Project personnel received numerous unsolicited reports from fishermen regarding an unusually high concentration of sea otters in the channels of the western Copper River Delta in 1988. Many voiced concern over the increase in sea otters and the potential impact on local shellfish stocks. Others reported an unprecedented frequency of incidental sea otter encounters.

Encounters between drift net fishermen and sea otters were most frequently observed in the surf and channel areas surrounding Egg Island. Summer use of these areas by mother-pup aggregations has been reported since 1988 (Monnett and Rotterman 1988, Wynne 1989). Although drift net recognition and avoidance by several adult sea otters (including females with pups) was observed, sea otter pups apparently were more vulnerable to entanglement due to their inexperience with drift nets. As a result, the potential for drift net encounters in these areas was high and was further exacerbated during very low tides.

Sea otters encountered 12 of the 387 net sets observed in 1988 and 1989. Eighteen of 23 sea otters (78%) actively avoided the drift net by swimming over the corkline, or under, around, or away from the net. Four of the five sea otters that became entangled escaped alone or with maternal assistance. One was released unharmed by the attendant fisherman. No mortalities were observed.

The fate of sea otters entangled in drift nets is largely determined by the fisherman's ability and willingness to remove them unharmed. The capture of sea otters in this fishery is unintentional and the majority of drift net encounters do not result in entanglement or drowning. While most sea otters are able to free themselves, others must eventually be removed by the fisherman. As witnessed in the field sample, small otters can be rolled out of the drift net or released unharmed by breaking several meshes of the net. This may not always occur, however, as indicated by the recovery of beached sea otter carcasses bearing bullet holes and skull fractures. Skull fracture mortality may reflect both intentional killing and unintentional death resulting from the fishermen's efforts to stun the sea otter to facilitate release. The removal technique used was dependent to a large degree on the size and temperament of the entangled sea otter. Although fishing-related sea otter mortality was indicated by the 1988 and 1989 beach survey results, none was observed in the field sample.

Sea otter numbers have increased in the Orca Inlet-Egg Island area since the early 1970s as a result of eastward expansion from Prince William Sound (Pitcher 1975, Simon-Jackson 1986, Monnett and Rotterman 1988, Wynne 1989). As anticipated, this has resulted in an increased potential for indirect (competition for prey) and direct (drift net encounters) conflicts with commercial fishermen in the area. Matkin and Fay (1978) considered the incidental capture and live-release of three sea otters from one set in 1978 an unusual occurrence. Simon-Jackson (1987) concluded that sea otter-drift net conflicts were infrequent in the Egg Island area because sea otters and fishermen were not present in the same areas at the same time.

The recent increased use of this area by female-pup aggregations, however, has apparently enhanced the potential for drift net encounters. The incidental entanglement of five sea otters in four drift nets was observed during 1988 and 1989 field sampling. During aerial surveys in the Egg Island area an additional two drift net sets entangled 10 sea otters (Wynne 1989). Although less than 1% of sampled drift nets were observed to entangle sea otters (Wynne 1989), encounter rates likely will increase as the population expands eastward and the number of inexperienced sea otters in the area increases.

Drift net encounters are not the only cause of sea otter mortality on the Copper River Delta. If they were, a preponderance of females and inexperienced pups would be expected in carcass counts. Males, however, comprised the majority (74%) of sea otter carcasses examined during 1988 and 1989 beach surveys. A minority (29%) of sea otter carcasses examined were classified as young of the year (Table 11).

Harbor porpoises. An unknown fraction of incidental harbor porpoise entanglement results in death. The one harbor porpoise observed entangled in the field sample was released unharmed. Three of 17 harbor porpoises examined during beach surveys in 1988 and 1989, however, apparently drowned, as evidenced by the presence of gillnet injuries around their flukes and flippers. Harbor porpoises are particularly susceptible to drowning due to their small body size and passive behavior when entangled. Porpoises entangled near the corkline, however, may be able to surface for air and be released unharmed, as observed in the field sample.

The location and nature of harbor porpoise conflicts with salmon drift nets observed in this study are similar to those reported in 1978 (Matkin and Fay 1980). As in 1978, it appears that entanglement is unintentional and occurs most frequently in offshore sets. Although beach surveys indicate at least three porpoises drowned in gillnets, there is no way to estimate a gillnet-related mortality rate for this species. Because the status and dynamics of the harbor porpoise population in the northern Gulf of Alaska are unknown, it is difficult to assess the impact of drift net-related incidental mortality.

Indirect Biological Interactions

Marine mammals and commercial fisheries interact both directly through physical interactions and indirectly through biological or ecological interactions. This study provided an overview of direct conflicts between marine mammals and the Copper River salmon drift net fishery, including gear and catch damage and marine mammal take. Although indirect biological interactions were not assessed in this study, they warrant recognition in any discussion of interactions between the salmon fishery and marine mammals on the Copper River Delta.

Indirect marine mammal-fishery interactions involve complex ecological relationships between upper level predators and their prey, including simple predator-prey relationships, predator-predator relationships, and complex secondary interrelationships. Examples of each relationship occur on the Copper River Delta where marine mammals and fishermen function as upper level predators on fish and shellfish stocks. Although these relationships are poorly understood, they carry serious implications for both marine mammal and fisheries management and deserve increased attention.

Much attention has focused on the negative effects of mutual exploitation of fish stocks by marine mammals and commercial fisheries. These interactions are difficult to document (Bowen 1985, Lowry and Frost 1985) but have been inferred from circumstantial evidence and explored through simulation modelling (Laevastu and Larkins 1981, Beddington and de la Mare 1985, Swartzman and Haar 1985). Recent reports suggest a high correlation between regional northern sea lion declines and the overharvest of walleye pollock stocks in the eastern Aleutians and central Gulf of Alaska (Loughlin and Merrick 1989, Lowry et al. 1989).

Conversely, marine mammal populations are known to respond positively to increases in per capita prey availability (Bowen 1985, Lowry et al. 1989). Such an increase has occurred in the Prince William Sound-Copper River area where Prince William Sound Aquaculture Corporation hatcheries increased pink salmon production from 0.15 million fish in 1978 to 18.3 million fish in 1987 (ADFG, unpublished report). The relative abundance and stability of northern sea lion numbers on rookeries south and east of Prince William Sound may reflect the benefits of enhanced salmon stocks on this opportunistic predator. Further research is needed to assess the degree and extent to which salmon enhancement is benefitting local pinnipeds.

Direct marine mammal-fishery conflicts may also be affected by the biological interaction of predators and alternate prey stocks. Evidence suggests that a change in the distribution and abundance of forage fish outside the delta may have contributed to the reduced presence and foraging of northern sea lions on salmon on the Copper River Delta in 1989. This may have resulted in the reduced levels of competition, gear conflict, and drift net-related northern sea lion mortality observed on the delta in 1989. Assessment of local northern sea lion prey use and availability would improve our understanding of direct and indirect drift net interactions and possibly lead to conflict resolution.

CONCLUSIONS

Conflicts between marine mammals and salmon drift net fishermen have occurred on the Copper River Delta for decades. The majority of conflicts have resulted from the scavenging of netted salmon by pinnipeds and the incidental entanglement of sea otters and cetaceans. Incidental and intentional marine mammal mortality have resulted from these encounters.

Significant changes in the status of the species involved in these conflicts and concern for potential management implications for the drift net fishery prompted a re-evaluation of marine mammal interactions with the Copper River salmon drift net fishery in 1988 and 1989.

This study employed a combination of three sampling efforts—field observations, dockside interviews, and beached carcass surveys—to provide an overview of current marine mammal interactions with the salmon drift net fishery on the Copper River Delta. However, due to limited sample size and biases, even the cumulative results of these samples suggest only trends and patterns and do not document fishery-wide take levels. Among these trends:

1. Scavenging of netted salmon and damage to drift nets by harbor seals and northern sea lions continue on the Copper River Delta. Incidental and intentional marine mammal mortality as a result of drift net encounters also continue.

2. Conflicts are not uniformly distributed in either time or space. Individual losses and mammal take rates vary regionally, seasonally, and annually and cannot be readily extrapolated either geographically or seasonally.

3. Conflicts are species-specific. The seasonal and regional distribution and behavior of marine mammals on the Copper River Delta determine the probability and results of encounters with drift nets.

   a. Northern sea lion conflicts occur predominantly in May and early June and are most frequent in surf and nearshore waters near the entrances to the Copper River. Northern sea lions scavenge netted salmon and are responsible for the majority of marine mammal damage to drift nets. Sea lion conflicts were significantly reduced in 1989. Most sea lions broke through nets without entanglement; take was mostly intentional, resulting from fishermen defending their gear and catch.

   b. Harbor seal conflicts appear to be most severe in August and September for drift netters fishing in the surf and channels. Many of the harbor seals involved in drift net conflicts appear to be recently weaned pups born on sandbars in the Copper River.

   c. Sea otter distribution is limited to the western region of the delta where they most frequently encounter drift nets set in channels or surf. Conflicts in 1988 and 1989 were most frequent when mother-pup pairs and drift net fishermen were using the same tidally restricted channels. Although it appears most sea otters can escape unassisted or are released unharmed from drift nets with the fisherman's assistance, some incidental and intentional mortality results from entanglement.

   d. Porpoises and other cetaceans were incidentally caught in drift nets set in nearshore and offshore waters throughout the delta. Although larger cetaceans are reportedly able to break through nets, smaller animals, including the harbor porpoise, must be assisted in release and may drown before assistance is available.

4. A conservative estimate of financial loss due to pinniped depredation on salmon in the Copper River and Bering River districts in 1988 represents less that 1% of the ex-vessel value of salmon landed.

5. Although the occurrence of incidental and intentional take was too infrequent and dispersed to establish a realistic estimate of its rate throughout the fishery, the 1988 and 1989 data show a significant reduction in drift net-related pinniped mortality.

6. The observed successful release of entangled sea otters and cetaceans shows that not all incidental captures are lethal and demonstrates the need and feasibility of informing fishermen of nonlethal removal techniques.

7. Drift net conflicts with pinnipeds are likely to continue on the Copper River Delta despite population declines elsewhere. Enhanced protection for northern sea lions granted in 1990 will make deterrence with firearms illegal and will necessitate the development of an extensive education program and establishment of viable nonlethal deterrents.

8. Cooperation of salmon drift net fishermen was basic to the successful collection of data in this study and will be essential to resolution of marine mammal conflicts on the Copper River Delta and elsewhere.

RECOMMENDATIONS

Marine mammal-drift net conflicts on the Copper River Delta are species-specific. Therefore, future documentation and mitigation should address species-specific goals. Pinniped conflicts, for instance, are based on predation of netted salmon while sea otter and porpoise conflicts are a consequence of incidental encounters. Each has a particular regional and seasonal pattern and potential for resolution. These patterns should be used to stratify sampling effort in future assessments and mitigation of conflicts affecting each species.

Marine mammal take appears to be infrequent and clumped in distribution. Therefore, an enormous sampling effort is required to accurately document marine mammal-drift net conflicts on the Copper River Delta. Stratifying samples based on species-specific objectives and increasing observer effort would provide a greater sample size and increase statistical confidence in the observed results.

Despite the potential for statistical limitations and bias, the use of observers aboard drift net vessels offered several advantages. Most important, it increased observation opportunities and encouraged dialogue between researchers and fishermen which may prove critical in the understanding and future resolution of marine mammal conflicts. Due to the small size of most drift net vessels, future observers of the Copper River drift net fleet will likely operate from independent research vessels. To ensure that future observer effort adequately samples marine mammal-drift net interactions, a minimum of one complete drift cycle (set, soak, retrieval) should be observed for each sampled vessel.

The firm, expansive beaches of the Copper River Delta barrier islands provide a unique and easily accessible sample of carcasses from which to monitor local marine mammal mortality. Surveys for beached carcasses should be continued and refined to provide an index with which to monitor species-specific changes in regional mortality and verify any observational surveys on the delta. More thorough necropsies and more frequent flights should be conducted to determine the source and rate of fishing-related mortality on the Copper River Delta. Refinement of these surveys should involve assessment of currently unquantified variables, including current and carcass flotation patterns and the rates of carcass deposition, decomposition, and loss.

An immediate priority should be the development and demonstration of viable nonlethal deterrents for nuisance animals. Although acoustic devices have met with limited success in deterring sea lions elsewhere (Mate and Harvey 1987), the effectiveness of these and other deterrents including rubber bullets and cracker shells should be systematically tested on the Copper River Delta.

An education program should be established to inform the fishing industry of recent changes in the legal and biological status of the northern sea lion and the availability of nonlethal deterrents, newly imposed federal regulations on the reporting of marine mammal interactions, and proper techniques for the live-release of sea otters, porpoises, and large cetaceans from drift nets. Future research efforts on the Copper River Delta should seek to:

1. Stratify field sampling to provide more intensive coverage of species-specific conflicts.

2. Refine the carcass survey and conduct necessary drift studies to facilitate its use as a valid index of marine mammal mortality on the delta.

3. Continue the use of at-sea observers to maintain and encourage cooperation with area fishermen.

4. Evaluate the nature and effects of indirect interactions between marine mammals and the Copper River salmon fishery.

Currently, the data are lacking to adequately assess ecological interactions between marine predators, including marine mammals and commercial fishermen, and fish stocks on the delta. Assessment of indirect interactions requires more complete baseline information on predator population dynamics, prey availability and use, and the dynamics of target and alternate prey populations.

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