MARINE MAMMAL AND FISHERY INTERACTIONS

ON THE COPPER RIVER DELTA AND

IN PRINCE WILLIAM SOUND, ALASKA

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THESIS

Presented to the Faculty of the

University of Alaska in Partial Fulfillment

of the Requirements

for the Degree of

MASTER OF SCIENCE

By

Craig O. Matkin, B.A.

Fairbanks, Alaska

December, 1980

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ABSTRACT

An assessment of rate of damage to netted fishes and to fishing gear caused by marine mammals, and of rate of incidental catch and kill of marine mammals by fishermen, was undertaken for the salmon drift gillnet fisheries of the Copper River-Prince William Sound area, Alaska, in 1977 and 1978. Amounts of damage to netted fishes ranged from approximately 1.8 to 8.3 percent of the total catch. Damages were attributed to Steller sea lions (*Eumetopias jubatus*), which also were responsible for the majority of damages to nets, and to harbor seals (*Phoca vitulina*). Of the approximately 1000 mammals incidentally killed in 1978, about half were harbor seals and 40% were sea lions; the remainder were harbor and Dall porpoises (*Phocoena phocoena* and *Phocoenoides dalli*) and sea otters (*Enhydra lutris*). Recommendations are made for modification of fishing methods to reduce the damages by and incidental kill of marine mammals.

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INTRODUCTION

Marine mammals have been recognized for a long time as competitors with the world's commercial fisheries, in that they consume fishes from the same stocks that are harvested for human consumption. In most regions, this is not regarded as having a serious impact on the availability of fishes for commercial harvest; however, in areas where more direct effects are felt through damages to fishing gear or removal of fishes from the nets, there is, understandably, a good deal of antagonism between the fishermen and the mammals.

There are numerous popular accounts of interference by marine mammals with several of the world's fisheries, but there is a remarkable scarcity of data on marine mammal-fishery interactions in the scientific literature. The damages done to both captured and free-swimming fishes in the Scottish salmon fisheries, however, have been documented in a series of papers.

Rae and Shearer (1965) surveyed the fixed engine fishery on the Scottish coast from 1959-1963. The nets (fixed engines) basically consist of a leader of netting which stretches seaward from the shore and serves to guide the fishes into the trap on the seaward end. Gray seals (*Halichoerus grypus*) frequently remove fishes from the trap end of the net and/or use the configuration of the net to aid in the capture of free-swimming salmon. Fishermen and net tenders at each fishing station were asked to record sightings of seals in the vicinity of the gear, along with other pertinent information. Each sighting was interpreted as indicative of removal of at least one fish from the gear.

Seals that occasionally became caught or accidentally trapped and drowned also were recorded by the fishermen, as were any direct observations of seal predation or observations of partially damaged fishes.

In that study, Rae and Shearer (1965) found as high as 6.9% loss of salmon from the total catch by all fishing methods in eastern Scotland due to gray seal depredations and even higher percentages in certain fixed net areas on the Scottish east coast. Net damage was measured as the percentage of nets that suffered any type of damage by seals. At nearly half of the stations, less than 5% of the nets showed damage, while at some stations damage was inflicted to over 30% of the nets. It should be noted that this was entirely survey data and that field observations by the researchers was not part of the study.

Of the salmon that were damaged, not all were completely destroyed. Of those examined by Rae (1960) at the Aberdeen fish market in 1958 and 1959, about 5% caught at the mouth of the River Dee were damaged in some manner by seals but still were marketable. Apparently, old scars as well as those received while in the nets were included in this tally. From information provided by fishermen, Rae (1960) concluded that from 5 to 15 percent of the catch on the entire Scottish coast was similarly damaged, although up to 50% of individual catches on some days were damaged.

Rae and Shearer (1965) also examined damaged salmon at market from 1961 to 1964, with similar findings. Fishes from the River Dee at Aberdeen and from the Kincardineshire and Angus coasts showed annual damages at the rate of from 2.7 to 7.4 percent. In that study, 96 percent of the damaged salmon had been clawed and 4 percent had been bitten or toothmarked by seals. Somewhat less than two-thirds of the fishes examined had recent marks; the wounds on the remainder were in the process of healing.

Traditionally, the Scottish salmon fishery has been a fixed net-trap fishery. However, from 1960 to 1962, drift gill net fishing was allowed. In that period, reports were received of up to 50% of catch being damaged, many of the fishes being unmarketable. Gray seals frequently were entangled and drowned in the drift nets. Experimental test fishing at Berick, during four weeks in January and February 1963, yielded 70 damaged fishes (24%) out of 286 captured (Rae and Shearer, 1965). Gray seals frequently were seen near the nets. In subsequent test fishing, damages were reduced by moving along the net and removing fishes as they were caught. In test gillnetting at other locations, damages were not as severe.

Lockie (1959, 1962) examined damages to nets in the Scottish fisheries by survey and estimated the total losses to the coastal salmon fisheries in the Tweed district. He estimated that young gray seals consumed about 3% of the total catch through predation on free-swimming fishes. The catch was made up principally of Atlantic salmon (*Salmo salar*), and sea trout (*S. trutta*). An additional unmeasured loss was attributed to older seals. Observations by Rae and Shearer (1965) indicated that a large proportion of the gray seal predation was on salmon, and that as much as 7 percent of the average annual catch (27,800 fishes) on the River Tweed was killed and eaten before reaching the nets.

The estimated overall loss to the Scottish salmon fisheries due to predation by gray seals was 2% of the total catch.

In studies of the feeding habits of seals in Scottish waters, Rae (1968) found by analysis of stomach contents that the food of the gray seal consists chiefly of salmonids and gadoids, with salmon (*Salmo salar*), cod (*Gadus callarias*), whiting (*G. merlangus*), and saithe (*G. virens*), the principal prey. The harbor or common seal (*Phoca vitulina*), which is more confined to sheltered waters, appears to prey heavily on gadoids, particularly saithe and whiting, and to a lesser degree on salmon, pleuronectids and clupeoids; however, evidence from commercial sources indicates that predation by the common seal on salmon may be high in estuaries and river mouths. On the Scottish coast, unlike the Alaskan coast at the present time, there are few fishes of no commercial value. Therefore, the prey of seals consist of the commercially valuable salmonids, gadoids, pleuronectids, and clupeoids, which also are those species that occur in greatest concentration in Scottish waters.

The expanding gray seal population of Scottish waters has continued to exert increasing pressure on the fisheries, and the issue has gained international publicity as a result of a recent proposal to reduce the gray seal population (Summers, 1978). This proposal was part of a program designed to prevent further expansion of the population (currently estimated at 50,000 animals) and to maintain the Orkney/Outer Hebrides stock at approximately 35,000 individuals (Summers, 1978). The expansion of the population in recent years is thought to have resulted from reduced hunting pressure by man following protective legislation and changes in local economies.

The interactions of marine mammals with the salmon fisheries of the Pacific coast of North America have not been examined in such detail as the Scottish fisheries. Briggs and Davis (1972) made observations of California sea lion (*Zalophus californianus*) depredations on the salmon troll fishery in Monterey Bay, California from April to September 1969. Although their sample size was small (0.21% of the total catch), it indicated that 4.1% of the catch was removed from the gear. Difficulties encountered during that study included the inability to positively identify the species of fish removed from the hook (in all cases it was believed to be *Oncorhynchus* sp.). Sea lions also were observed at the surface after capturing free-swimming salmon in seven instances.

Farther north along the Pacific coast, gillnetting of salmon is a major fishery. On the Skeena River in British Columbia, Fisher (1952) estimated from the catches by five fishermen that monetary losses from damages inflicted by harbor seals to Chinook (king) salmon (*O. tshawytscha*) represented approximately 7 percent of the total value of the catch.

Recently, the Oregon Department of Fish and Wildlife measured the incidence of damages by seals to salmonids in the lower Columbia River gillnet fishery (Hirose, 1977). From 1972 to 1976, during routine sampling of the gillnet catch, note was made of "any recent break(s) or slash(es) penetrating the skin or an obvious bite" on the body of the salmon. Any fish so afflicted was designated as seal-damaged. Damages to the entire fishery were extrapolated by season from percentages of damaged fishes examined. One problem in this methodology is the possible classification of damage inflicted by other marine mammals or sharks as "seal-damage". Another is the difficulty of differentiating between damages sustained while free swimming from damages sustained while in the net.

The incidence of damaged salmonids in that study ranged from 1.0 to 2.4 percent in 1972 to 1976 (evidently these all were salable fishes). Interestingly, there has been no trend of increasing rates of damage since 1972, when the seals were given full protection by the Marine Mammal Protection Act. Total damage to the catch has been greatest during the autumn, when most of the catch is taken, but the highest rates of damage occurred in the spring and winter. In an attempt to supplement these data, log books were distributed to the fishermen for recording extent of marine mammal depredations; however, none of these logbooks was returned.

In Alaskan waters, seals and sea lions have been implicated in fishery depredations and gear damage since the advent of intensive commercial fishing there. Historically, the salmon fisheries of the Stikine and Taku estuaries in southeastern Alaska and of the Copper River-Prince William Sound district of southcentral Alaska have been regarded as "hot spots" in this conflict (Lensink, 1958). The mammals most frequently implicated as being responsible for the damages have been the harbor seal (*Phoca vitulina*) and the Steller sea lion (*Eumetopias jubatus*). Numerous other fish eating marine mammals, such as Dall's porpoise (*Phocoenoides dalli*), harbor porpoise (*Phocoena phocoena*), killer whale

(*Orcinus orca*), and sea otter (*Enhydra lutris*) also occur in these areas and are associated with the fisheries, but they have not been considered as major contributors to the conflict (Appendix I). Some, such as the harbor porpoise, are killed incidental to fishery operations when they become entangled in the gear.

The biology of the harbor seal and Steller sea lion in Alaska were the focus of work by Imler and Sarber (1947), who also examined fishery depredations by harbor seals on the Copper and Stikine river deltas in Alaska. On the Copper River from 28 May to 6 June 1946 a total of 10,863 gillnetted salmon were inspected for damages done by harbor seals. The total loss observed was 92 fish (0.85 percent of total catch). The actual damage was estimated to be greater (approximately 2 percent), since the total number of fishes examined did not include those immediately discarded by the fisherman or, of course, those totally removed from the net. No separation of salable from unsalable damaged fishes was indicated and no mention was made of any interaction of the fishery with sea lions. It was emphasized that some fishermen may experience much greater than average losses while others may find no damaged fish for weeks at a time. Imler and Sarber (1947) also stated that seal damage was so severe at certain times and localities that fishermen were forced to move to new grounds; however, this was uncommon, even on the Copper River delta.

On 5-6 September 1945 Imler and Sarber (1947) examined the catch of 21 vessels as they unloaded at buyers scows on the Stikine River, Alaska. Of the 2,044 silver salmon examined, 27 were unsalable and 32 were salable but were reduced in value by about 25 percent; thus, the damage was estimated at 1.7 percent of the day's catch. Currently, there are no estimates of damages on the Stikine River or in other parts of southeastern Alaska, although it has been indicated that some damages by harbor seals still are sustained on the Stikine and Taku Rivers, and that damages by sea lions occur during the Chilkat River fishery (ADF&G, Juneau, personal communication). Damage on the Stikine and Taku Rivers is thought to be less than in the past, because of the tendency for vessels to fish farther out from the river mouth, in areas where harbor seals are less concentrated (J. W. Brooks, personal communication).

The first attempt at solution of the problem of fishery depredations in southeastern and southcentral Alaska, through reduction of the offending marine mammal populations, was initiated in 1927 when a bounty was placed on seals nearly statewide (Alaska Stat., 1927). Apparently this action was initiated only on the basis of anecdotal information, rather than on definitive data on the feeding habits of the animals (Appendix II). In 1951, the Department of Fisheries of the, then, Territory of Alaska began a program of more direct control by reduction of harbor seal populations "in the areas where they caused heavy damage to commercial fisheries" (Andersen, 1951, p. 44). Two areas, the Stikine River in southeastern Alaska and the Copper River delta in the northern Gulf of Alaska, were selected for intensive effort, since these were the "two areas where the greatest damage was done" by seals (*Ibid.*). Over the 8-yr period (1951-1958) of its existence, this program led to the destruction of some 5,000 harbor seals on the Stikine

River by shooting and more than 30,000 on the Copper River delta by dynamite charges (Lensink, 1958). While it was felt "that depredations by seals can be effectively prevented" by such a program (Lensink, 1958, p. 93), the real effects will never be known, inasmuch as there seems to have been no actual measurement, either before or after, of the kinds and rates of occurrence of damages by the seals to the fisheries.

In the 1950's, a program of regulated harvests of harbor seals and Steller sea lions for commercial use also was begun by the Territorial Government. This was continued after statehood by the Alaska Department of Fish and Game (ADF&G). The bounty system, finally recognized as ineffective and overly expensive (Lensink, 1958), was terminated by the ADF&G in the 1960's. Under the controlled harvest system, seal and sea lion hunting was done mainly outside the fishing season and was directed more at certain of the larger breeding populations than at the animals in the conflict area. It is questionable whether this was as effective as the direct control program; however, it was not designed as "control" *per se*. It may have had some regulating effect, since the harbor seals in the Copper River estuary are not residents; apparently, they move in and out of the area from concentrations along the Gulf coast and in Prince William Sound (Pitcher, 1977). The seals travel well up the Copper River during the spring and summer months (Pitcher, 1977; S. W. Stoker, unpublished) and have been sighted in the salmon spawning areas of the Bering River and Eyak Lake (Julius Reynolds, personal communication).

Since passage of the Marine Mammal Protection Act of 1972, there has been no sanctioned "take" of marine mammals in the Copper River-

Prince William Sound area, other than for native subsistence purposes (Appendix III) and as incidental kill by the fisheries. In recent years, however, an increase in depredations by both harbor seals and Steller sea lions has been reported there by the salmon gillnet fishermen.

The nature of this conflict was investigated preliminarily in 1977, while the author was employed there as a commercial fisherman. A more systematic and intensive study of it was completed during the 1978 salmon gillnet season. This study was designed to measure the kinds and amounts of damages caused by marine mammals to fishes in the net and to the nets themselves in the Copper River-Bering River-Prince William Sound salmon drift gillnet fisheries. In addition, it would assess the rates of incidental kill of marine mammals by those fisheries, and would seek some means to reduce marine mammal-fishery interactions through analysis of relationships to spatial, temporal, and other factors.

DESCRIPTION OF THE STUDY AREAS

The Copper River-Prince William Sound region is situated on the northern shore of the Gulf of Alaska (Figure 1). The Copper River and adjacent Bering River fishing districts extend more than 80 miles (128 km) from Cape Suckling on the east to Hook Point, Hinchinbrook Island on the west. This area, particularly the delta of the Copper River, is distinctively different topographically from other coastal areas on the Gulf. The broad Copper River delta is characterized by a myriad of sloughs and side channels that diverge from the main channel of the river in a complex pattern before emerging as a few main channels onto

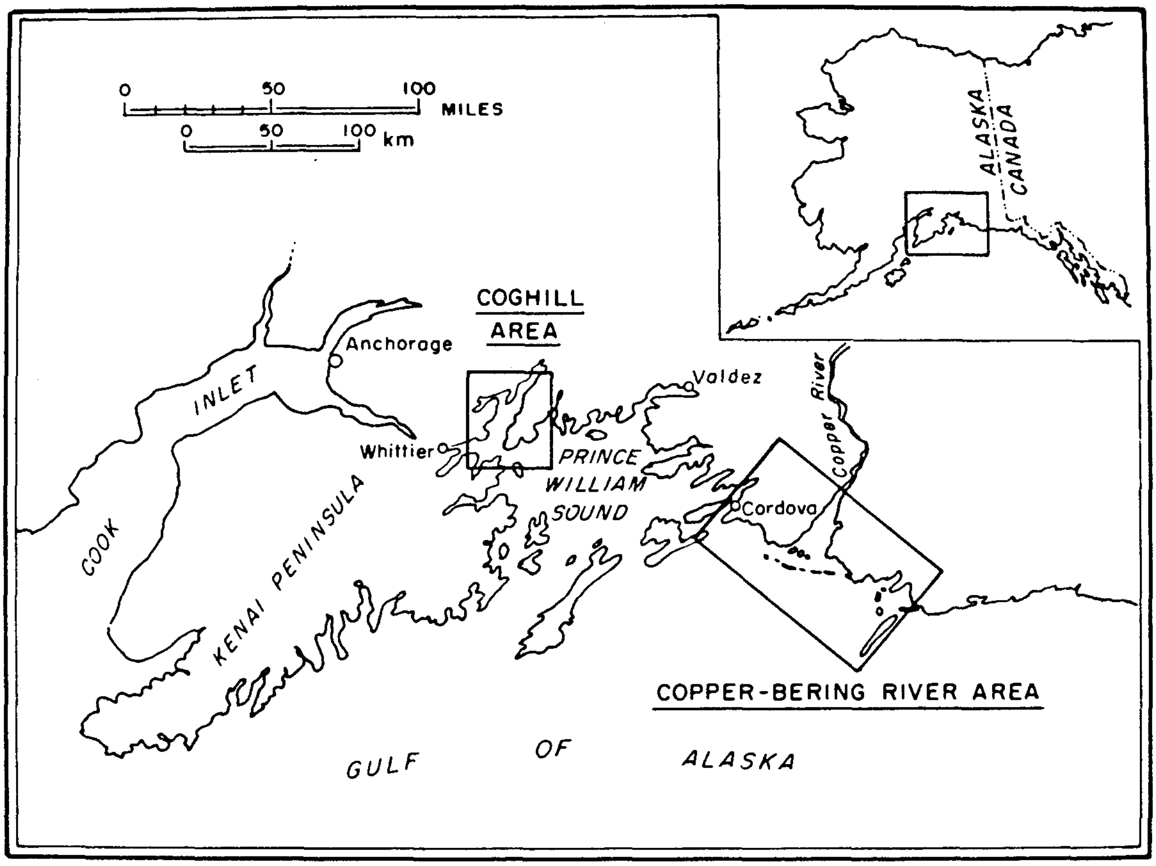

Figure 1. Location of the study areas on the northern shore of the Gulf of Alaska.

the intertidal sand and mud flats. These flats extend seaward up to 8 miles (13 km) to the outer barrier islands (Figure 2). The uplift of nearly 2 meters that occurred on the Copper River delta during the 1964 Alaskan earthquake had a significant impact on these intertidal flats. Except for the deeper channels, the flats are now almost completely exposed at each low tide; at high tide they become an open shallow estuary. The maximal tidal amplitude at Cordova is 18.2 feet (5.5 m); on the Copper River flats, this is considerably modified by strong winds and storms off the Gulf of Alaska, which produce differences of 1 meter or more between actual and predicted high and low tide levels (Isleib and Kessel, 1973). As a result of these tides and the freshwater discharge from the rivers, very strong currents occur in the restricted channels of the delta during ebb and flood stages.

The outer barrier islands separate and provide some protection to the tideflats from the open Gulf of Alaska. The individual barrier islands are separated by shallow passages ("entrances"), which change in form and depth annually by deposition and erosion. The massive sediment load transported by the Copper River severely restricts visibility in the waters on the flats, as well as for several miles outside the barrier islands.

There are six major bar entrances on the Copper River delta; from west to east they are Strawberry, Egg Island, Pete Dahl, Grass Island, Kokenhenik, and Softuk. These names are used by the fishermen to describe the adjacent areas, as well as the entrances themselves. There is a single entrance to the Bering River via Controller Bay. Vessels

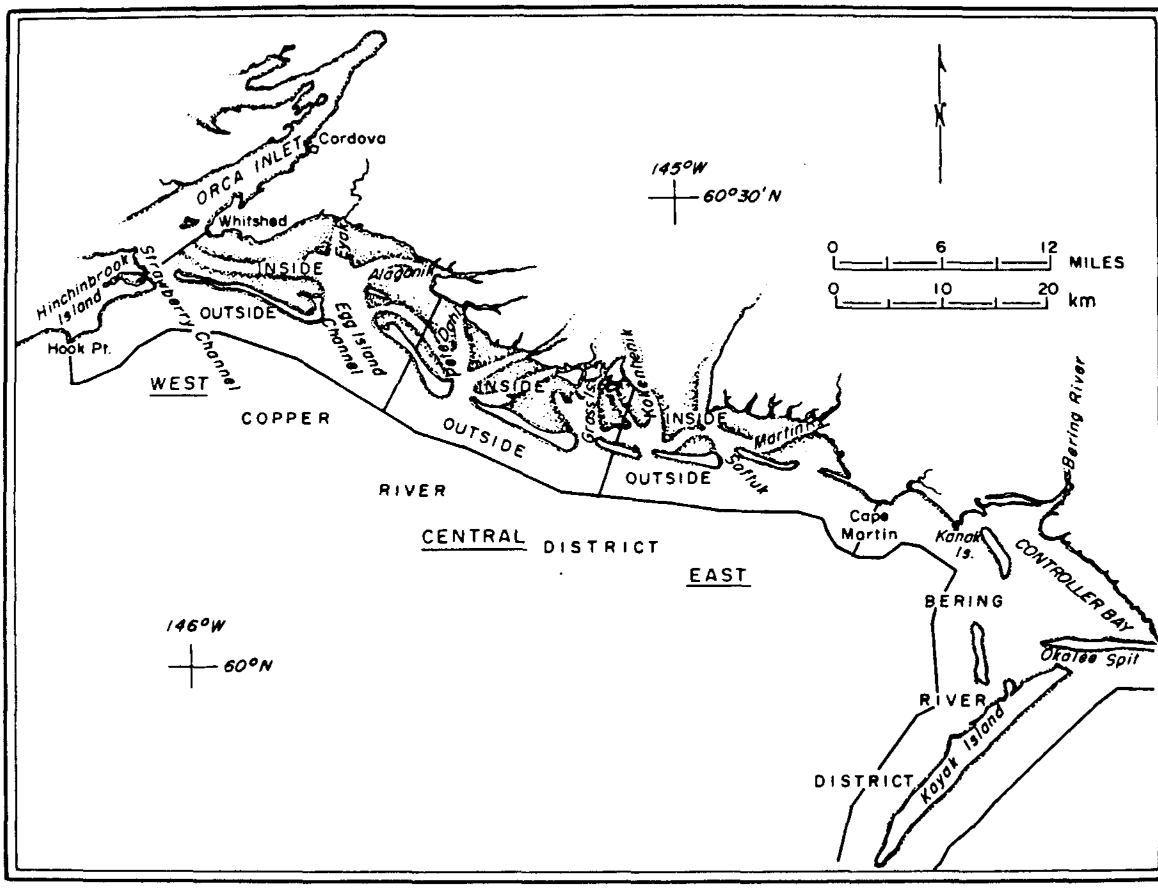

Figure 2. The Copper and Bering River districts, showing the main geographical features and the sampling subarea of the Copper River delta.

moving out into the open Gulf from the tidal flats or back onto the flats from the Gulf must pass through these entrances.

Water depth on the flats rarely exceeds 6 fathoms (11 m) even in the deeper channels, and the water outside the barrier islands also is relatively shallow. Out to 2 miles (3.2 km) offshore, water depths tend to be as little as 10 fathoms (18.3 m). The edge of the continental shelf is more than 35 miles (56 km) from shore.

During the field work in the Copper River district, sampling was done "inside" as well as "outside" the barrier islands, which required frequent movement in and out through the bar entrances. During periods of heavy seas and/or storms, the entrances were not negotiable by the research vessel; at such times, sampling was conducted only in the inside waters. As a safety precaution, even in fair weather, sampling of the outside waters was limited to about 1 mile (1.6 km) outside the barrier islands, although a few fishing vessels were sighted several miles farther out.

Fishing in Prince William Sound is done in more protected waters. The Sound itself is a large embayment of the Gulf of Alaska, approximately 80 miles (130 km) in diameter. Protection from the heavy seas is afforded by a series of large, wooded islands (Figure 1).
The waters within the Sound are mostly very deep (up to 475 fathoms = 870 m) and clear; the shoreline is precipitous and rocky with numerous fjords and rocky coves. Valley glaciers meet or enter tidewater at the head of several fjords, and in some areas, drifting glacial ice is prevalent seasonally.

The Coghill fishing district is located mainly in one of these fjords (Port Wells), in the northwestern corner of Prince William Sound (Figure 3). It is about 50 miles (81 km) by vessel from the open Gulf of Alaska and more than 70 miles (113 km) from the Copper River delta and Cordova. In the Coghill district, water depths of up to 420 m occur less than 1 km offshore. Some suspended glacial silt and associated organic material cloud the waters of the northern part of this district, but elsewhere, its waters are clear relative to those of the Copper River district. The Coghill River empties into the northern part of Port Wells and supports the principal runs of salmon in the district. These include red, chum, and pink salmon. As is typical of river systems in Prince William Sound, the Coghill River is very short; Coghill Lake, the origin of the river, is less than 3 miles (5 km) from tidewater. Tidal amplitude averages approximately 12.5 feet (3.8 m) in Port Wells (Isleib and Kessel, 1973).

The Coghill fishing district is one of three drift gillnet areas in Prince William Sound and is the one in which the primary salmon gillnet fishery occurs. Its waters are mostly well protected; fishing seldom is impaired by weather conditions, except at the southern, most exposed end of Esther Island. Generally, tides and currents also cause no problems, except among the offshore rocks, rocky islets and points. The rocky shoreline itself also can present a major hazard to navigation and fishing under certain conditions (e.g., fog or darkness).

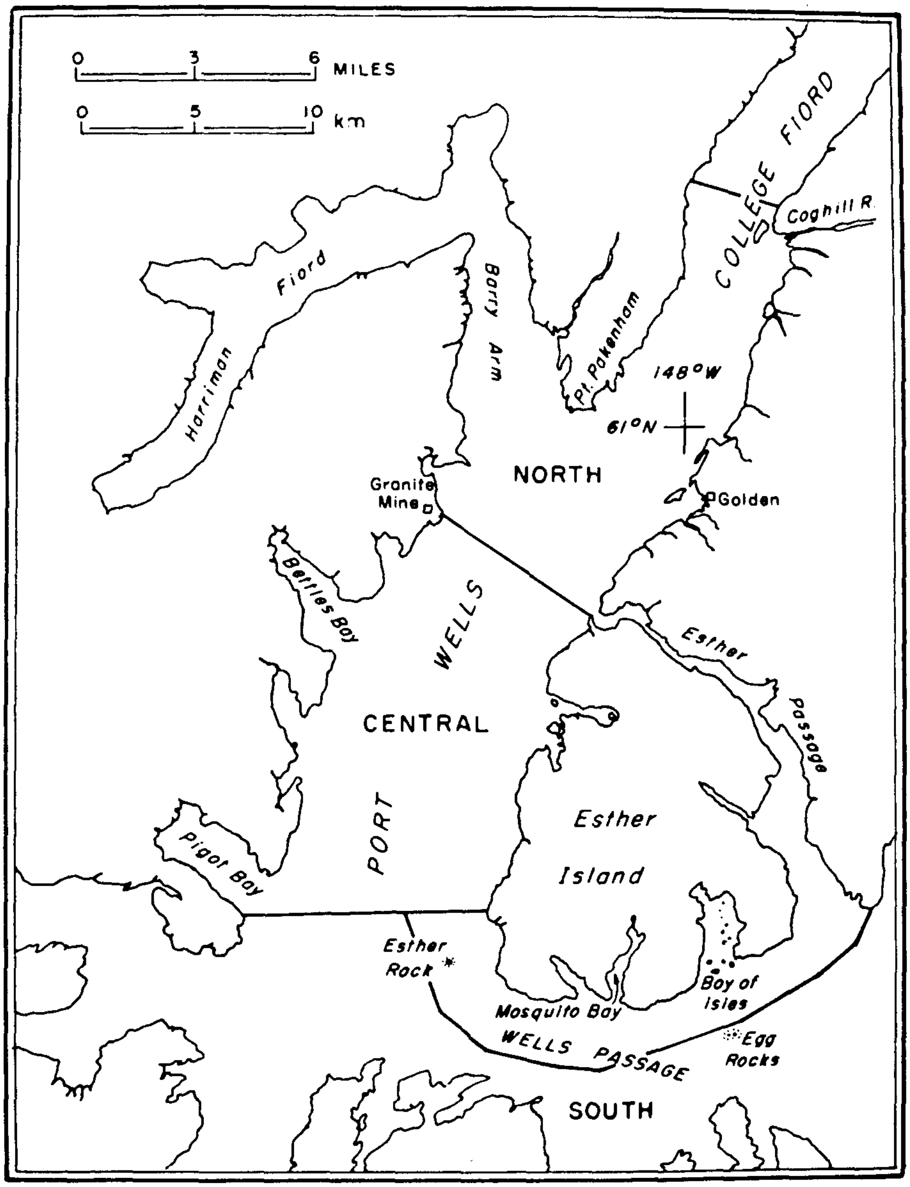

Figure 3. The Coghill district, showing the main geographical features and sampling subarea.

DESCRIPTION OF THE FISHERIES AND THEIR MANAGEMENT

The Alaska Department of Fish and Game (ADF&G) is the agency with primary responsibility for management of the salmon fisheries in Alaska. Biologists at the ADF&G office in Cordova have jurisdiction over the Copper River-Prince William Sound salmon management area, for which they set the open fishing seasons and can invoke "emergency closure" of any fishing district or sub-district within that area. The open fishing seasons generally are the same each year but may be shortened by emergency closure when conditions warrant it. Their judgements of the status of each fishery are based on continuous surveillance, mainly by aerial surveys, counts of fishes passing upstream, and analyses of catch per unit of effort. Emergency closure is invoked when the "escapement" (i.e. number of fishes evading the fishermen and reaching a given spawning area) is lower than required for adequate production. The ADF&G also is responsible for marking the boundaries of areas open to fishing, and for regulating the kinds and dimensions of gear (in this case, nets) used in each fishery.

Since the early 1970's, the salmon fisheries of Alaska have been restricted also by "limited-entry", in which a limit is placed on the number of "gear units" that can take part in a particular fishery or group of fisheries. A gear unit, in this case, is one boat with one net. The Copper River, Bering River, and Prince William Sound fishing districts comprise a single limited-entry area. Approximately 500 gear permits have been issued for salmon drift gillnetting in that area. These permits are permanent licenses, with an annual renewal fee, payable to the ADF&G. They may be bought and sold among the fishermen, at their discretion. The majority of permit holders are not full-time residents of Alaska but come north seasonally, mainly from Oregon and Washington, to participate in the fisheries. Individuals holding a limited-entry permit for a given area are allowed to catch and deliver fishes in any of the fishing districts within that area.

Although about 500 gear unit permits have been issued, the number of vessels participating in the Copper River-Prince William Sound salmon gillnet fisheries seldom exceeds 450. These are of several types, because of the wide variety of conditions encountered. For at least the past 15 years, small (7 to 8 m), nearly flat-bottomed, wooden (or fiberglass on wood) skiffs, with a small cabin forward, have been popular for use on the intertidal sand and mudflats, because of their ability to negotiate the shallow channels and bars of the Copper and Bering River deltas. They are known as "stern-pickers", because the net is dispensed and retrieved over the stern. Recently, larger (7 to 10 m) fiberglass-hulled boats have replaced many of the wooden skiffs. In these new boats, the cabin is aft and the fishing gear is deployed and retrieved from the bow; hence, they are known as "bow-pickers". The hull of these vessels is generally more "V"-shaped and many have been outfitted with an inboard engine having a water jet-propulsion unit. The latter allows operation in very shallow water and provides extreme maneuverability. Also, there has been a trend toward larger vessels, both bow-pickers and deeper draft stern-pickers, that are more suitable for fishing the deeper waters outside the barrier islands of the Copper River delta, even under stormy conditions.

The catch of salmon in this region includes five species: red or sockeye (*Oncorhynchus nerka*), king or chinook (*O. tshawytscha*), dog or chum (*O. keta*), humpback or pink (*O. gorbuscha*), and silver or coho (*O. kisutch*).

The legally prescribed (by ADF&G) length of the gillnet used by each vessel in this management area is 150 fathoms (274 m). Nearly all fishermen utilize this maximum allowed length of multifilament nylon net. Currently, there are no legal limits on the depth of the net; those commonly in use on the Copper River are about 28 feet (8.5 m) deep, while those in the deep water Coghill fishery are as much as 90 feet (27.4 m) deep. The mesh size of the net also is not prescribed by ADF&G regulation but is left to the fishermen's discretion. The choice of sizes is a function of the kind and size of salmon to be caught. On the Copper River in spring, the fishing is principally for red and king salmon, in the Coghill district, red salmon are most sought, but an increasing number of pink and chum salmon is caught as the season progresses. The autumn fishery on the Copper and Bering River deltas is almost entirely for silver salmon.

The net (one only per boat) is dispensed from a large metal or wooden reel, either over the stern (stern-picker) or over the bow (bow-picker). It is allowed to "soak" (remain in the water) for from 15 minutes to more than 8 hours, depending on the circumstances (i.e. the number of fishes present, the speed of the current, the drift of the vessel, the ambition of the fishermen, etc.). Generally, in most "sets", the net is soaked no more than two to three hours. Longer sets are avoided, because the fishermen feel that the number of "dropouts" (i.e. fishes that die, stiffen, and fall out of the net) increases with the length of the set. It is felt also that longer sets encourage depredations by seals and sea lions. Furthermore, frequent retrieval of the net allows it to be cleaned of undesirable debris. At all times while the net is in the water, the boat and net must remain unanchored and drifting, hence the term "drift gillnetting".

The style of fishing and the methods employed are as varied as the fishing vessels and types of gear that are utilized. On the Copper River, the larger boats sometimes make only long-term sets, well outside the barrier islands. The smaller boats fish principally in the shallower water generally with shorter sets. Some "work" the breaking surf on the outside of the barrier islands, the entrances or, as the tides permit, the inside channels. In the Coghill and other Prince William Sound districts, which are situated in deepwater fjords, fishing is done with deeper nets and longer sets.

The number of fishes caught per set of the net varies from none to several hundred. The average catch per set is less than 50 fishes. Any of these that are severely damaged are disposed of immediately; the undamaged and lightly damaged fishes are stored temporarily in the hold of the boat. Usually daily, the fishes in the hold are delivered to the nearest "cannery tender", which is a larger vessel with substantial refrigerated storage capacity used for transporting the fishes back to the processing plants on shore.

The Copper River spring salmon gillnet fishery usually begins in mid-May. The greatest fishing effort is made and the majority of fishes (red and king salmon) are caught in the first five weeks of that fishery. Typically, the Coghill drift gillnet fishery opens on or about 19 June and extends for five weeks. Thus, after the first five weeks of the Copper River fishery, fishing emphasis generally shifts to the Coghill, especially when there is a clear decline in the catch per unit of effort on the Copper River delta. The Bering River fishery generally is opened to gillnetting about the time of opening of the Coghill fishery, this tends to split the fleet to an extent between the Coghill, Bering, and Copper River districts. After closure of the Coghill, about 23 or 24 July, emphasis shifts back to the Copper and Bering River districts, which typically remain open until early October. Only a few of the licensed vessels are active throughout this period. Many of the vessels and fishermen (especially those from outside of Alaska) that participate in the spring and summer fisheries do not operate during the autumn silver salmon fishery, partly because of the stormy conditions at that time.

METHODS

Sampling Procedures

In the 1977 pilot study, fishermen were selectively interviewed at the end of each fishing week on the Cordova docks, during the spring Copper River salmon gillnet fishery (approximately 19 May to 19 June). Their total catch and interactions with marine mammals were recorded on a standard survey form (Appendix IV). In addition, general information and observations were collected when fishermen delivered fishes to the cannery tenders at the western end of the Copper River delta. Miscellaneous observations also were made while participating in the Prince William Sound salmon purse seine fishery.

In 1978 two methods were utilized for sampling the fishery. First, fishing operations and the interactions of marine mammals with them were observed and recorded directly on the fishing grounds. The data derived from this are referred to hereafter as the field sample. Second, data were gathered from individual boat operators by interview at the end of each week of fishing, as regards their results and observations during the previous week. This material is called the dockside sample.

For the field sampling, a 26-ft (7.9 m) gillnet skiff was operated by Matkin and a field assistant. The vessel was not equipped with fishing gear but was otherwise similar to vessels actively engaged in the fishery. The research vessel was capable of sleeping two researchers and of remaining on the fishing grounds indefinitely. Arrangements for supplies of food and fuel were made in advance with the cannery tenders.

In field sampling, initial contact was made visually with vessels that were actively fishing. Each vessel sighted was counted; selection of a vessel for sampling was made on the basis of a table of random numbers. The selected vessel was approached, and permission was requested of the operator to observe his fishing activities. At this time, the fisherman was questioned concerning his observations of marine mammals in the area and regarding any recent interactions with marine mammals.

If permission to observe was not granted, the next closest vessel was approached until a fisherman willing to cooperate was contacted.

Then, the research vessel either was tied up to the fishing vessel or remained in the vicinity, drifting or idling, depending on the sea state and the activity of the fisherman. Insofar as possible, one complete setting, soak, and retrieval of the net was observed at each boat sampled. The kind and number of marine mammals sighted around the net, the total number of fishes caught, the number of these that were damaged, the extent of damages to the net, and the number of marine mammals incidentally taken were recorded on a standard Field Data Form (Appendix V).

Generally, only one kind of marine mammal was sighted near the net during a given set. Thus, when the gear was retrieved, it usually was not difficult to identify the kind of mammal that had caused any damages. In cases where both harbor seals and Steller sea lions were present, the damages usually were classified as having been caused by "unidentified marine mammal". However, in some cases, the damages were so characteristic that they were easily attributed to seal or sea lion.

As illustrated in Figures 4-9, damages to fishes by sea lions tended to be far more extreme than those caused by harbor seals. Usually, sea lions left only the head or some other fragment of the fish in the net; occasionally they tore away only the head and left the body. A large hole in the net accompanied by a fragment of a fish generally was attributed to sea lions; harbor seals rarely penetrated the net. Harbor seals often stripped portions of the fishes' skin away from the body, leaving the underlying musculature mainly intact, or they ripped open the belly of the fish. Not infrequently, the seals took only a few bites from the head; occasionally, they removed it entirely. In some cases, damage

Figure 4. Red salmon from which the head has been removed by a harbor seal. This type of damage is done occasionally also by sea lions.

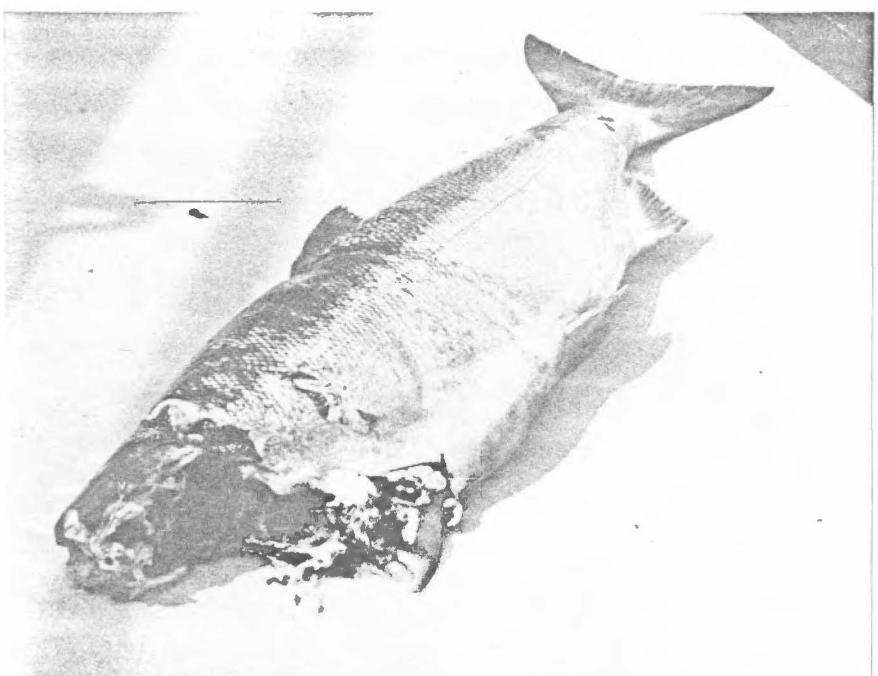

Figure 5. A damaged, salable red salmon showing net marks and head and viscera removed by a harbor seal. This fish could be sold at a reduced rate, about 50% below its market value if undamaged.

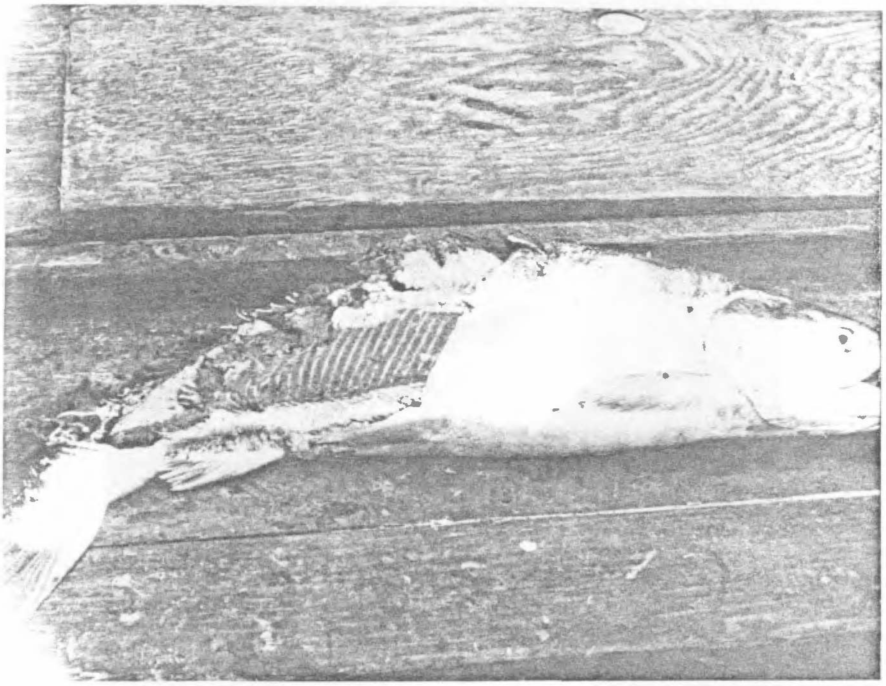

Figure 6. Damaged, unsalable red salmon from which the skin and part of the musculature have been stripped from the posterior part of the body. This is typical of damages by harbor seals to fishes in the net.

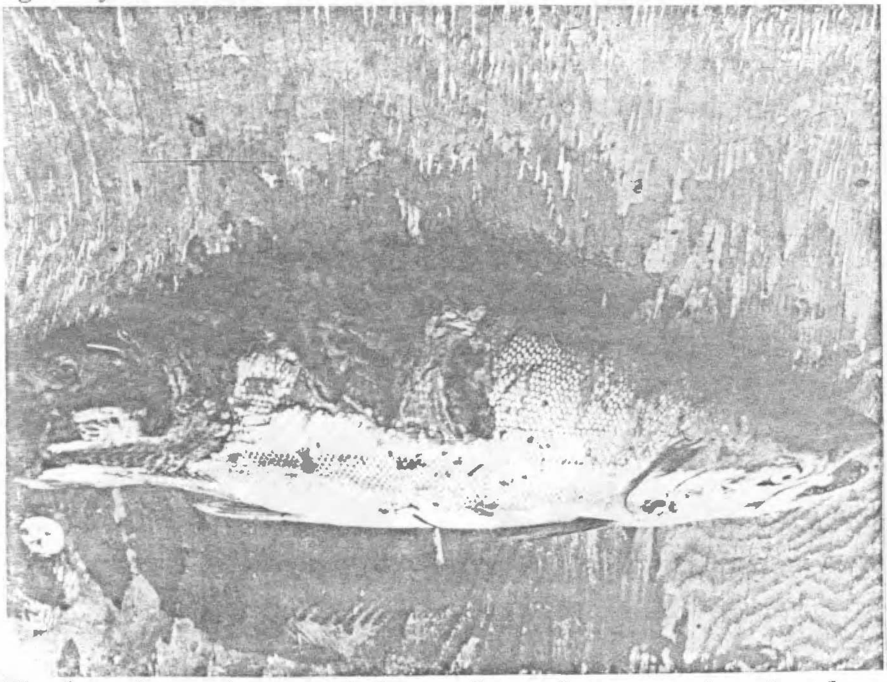

Figure 7. Slashes into the epaxial muscles of a netted red salmon. This type of damage is most often associated with the presence of harbor seals "working the gear".

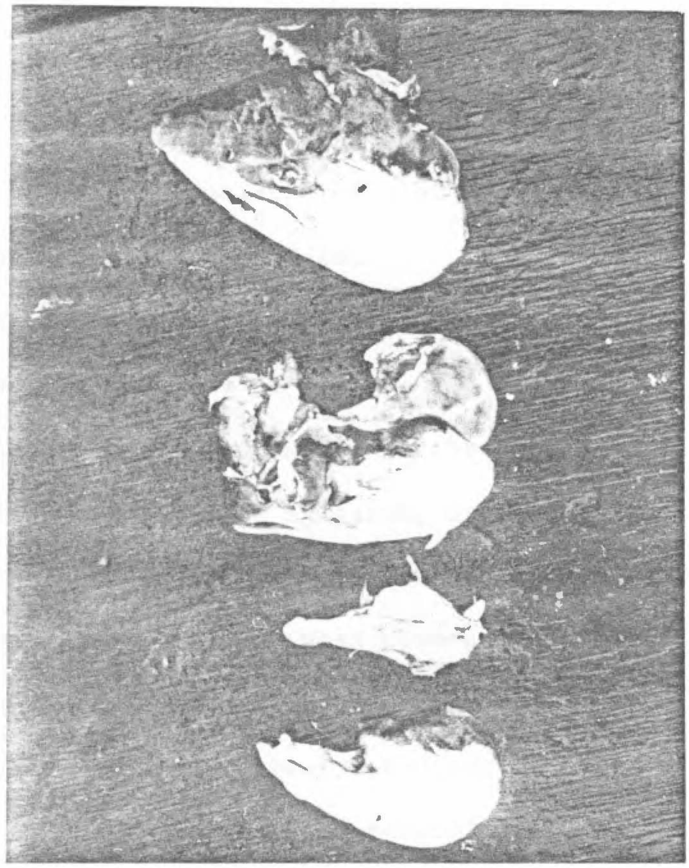

Figure 8. Remains typical of sea lion depredation on red salmon in the net. Four fishes were represented by these fragments, two of which were associated with large holes in the net.

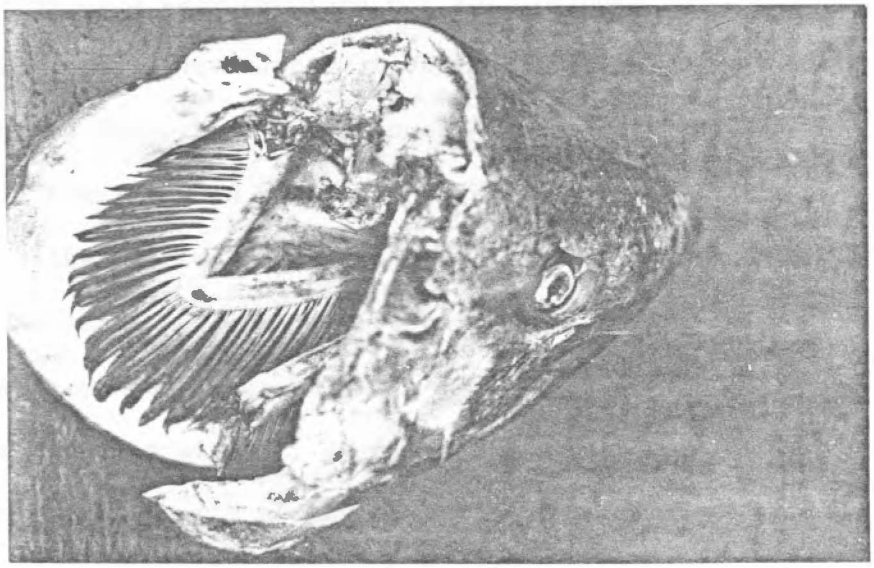

Figure 9. All that remained of a 25 lb (11 kg) king salmon after it was attacked in the net by a sea lion. The entire body of this fish was cleanly torn away, leaving only the head in the net.

to a netted fish by a seal consisted only of a slash or a bite across the ventral surface, beneath the gills.

In all cases, counts of the number of fishes damaged were conservative, since it was not possible to account for fishes totally removed from the net. Fishes loosely entangled in the mesh of the gillnet occasionally fall out when the net is agitated, as it sometimes is by marine mammals. No trace remains of such losses when the net is retrieved. Damages to nets were recorded only when obviously attributable to marine mammals, i.e. when damaged fishes were present adjacent to the hole.

In the dockside sampling, vessel operators arriving at the Cordova docks, returning by small aircraft, or remaining on the fishing grounds were interviewed at random at the end of each fishing week, until a sample of approximately thirty per week had been obtained. Those fishermen unwilling to provide data were recorded but not included in the sample. During the spring Copper River fishery, nearly all dockside interviews were conducted on the Cordova city or cannery docks. In the Coghill fishery, they were completed on the fishing grounds, since most of the fishermen remained there between fishing periods rather than returning to Cordova. In the autumn Copper River-Bering River silver salmon fishery, interviews were conducted principally on the Cordova docks; some were conducted at the city airport, as fishermen returned by small charter aircraft from distant parts of the Copper and Bering River districts. Each vessel operator was requested to report his total catch for the week, amounts and types of marine mammal damages to fishes and gear, the kinds of marine mammals that were identified as having inflicted the damages, the general locations of his fishing activities and interactions with marine mammals, and the amounts of incidental catch and/or kill of marine mammals (optional). This information was recorded on a standard Dockside Survey Form (Appendix VI).

Sample Design

For the May-June 1978 salmon gillnet fishery on the Copper River flats, there are potentially about 500 fishing permits (one per boat) issued by the Alaska Department of Fish and Game. In 1977, some 450 boats actually participated in the fishery, and about the same number was expected in 1978. The open season for this fishery usually is continuous from mid-May through the summer season (mid-August); however, most of the catch is taken in the first five weeks of fishing. Usually, there are two open fishing periods per week, the first from 0600 Monday to 0600 Wednesday (48 hrs), and the second from 1800 Thursday to 0600 Saturday (36 hrs). These conditions also were expected to be the same in 1978. However in actuality, the season was open for only three weeks, closed by emergency order for half of the second week, and closed indefinitely after the third week by ADF&G emergency order. The reason for this was the poor return of red salmon to the Copper River spawning areas.

For purposes of field sampling, the Copper River delta was divided into three subareas (West, Central, and East) utilizing the existing ADF&G sub-district boundaries (Figure 2). A natural division between the relatively protected "inside" waters of the delta and the "outside" waters open to the Gulf of Alaska is effected by the barrier islands, and this was used to subdivide further each of the three subareas.

The passages between the barrier islands were considered as "outside waters".

The ADF&G refers to the weeks of the year by number (i.e. 1 to 52). Over the past five years, the distribution of the deliveries of salmon to the cannery tenders per week, per subarea (West, Central, East) has been about the same each year, according to the records of the tenders receiving the fishes. Deliveries were greatest in the West during the first two weeks (21, 22), about equally distributed in the third week (23), and greatest in the East in the fourth and fifth weeks (24, 25). Predicting that comparable conditions would occur in 1978 (Table 1), the field sampling was stratified by subarea accordingly, assuming that the spatial distribution of the catch corresponds closely to that of the deliveries to the cannery tenders. Due to the large size of the area

Table 1. Predicted percentage distribution of weekly deliveries of salmon per subarea, Copper River spring fishery (based on 5-year means, 1973-1977, from cannery tender records).

	Fishing week					Weekly
Subarea	21	22	23	24	25	average
West	62%	51%	37%	32%	28%	42%
Central	26%	31%	29%	20%	24%	26%
East	12%	18%	34%	48%	47%	32%

(16 x 80 km) and the restricted visibility from the research boat (26-ft skiff) from which the sampling was to be done, it would be impossible to ascertain the actual distribution of effort at the time of sampling. In reality, the distribution of the deliveries compared very closely with the predicted pattern (Table 2).

Table 2. Actual percentage distribution of weekly deliveries of salmon per subarea, Copper River spring fishery, 1978 (from cannery tender records).

Subarea	Fishing week 20	21	22	Weekly average
West	60%	40%	54%	51%
Central	25%	33%	28%	29%
East	15%	28%	18%	20%

It was assumed that the catch could be representatively sampled by direct field observation of fishing activities of some randomly distributed proportion of the boats. It was estimated that, in each week of fishing, the research team would be able to intercept about 250 of the 450 possible boats. Of these, optimally, 10%, i.e. about 25 boats per week would be sampled (one boat per 3.4 hrs of open fishing). Fourteen of these would be sampled in the first (48-hr) open period and eleven in the second (36-hr) period. Selection of boats to be sampled from all those encountered would be on the basis of a table of random numbers from 1 to 250, and the weekly samples would be spatially stratified as shown

Table 3. Predicted number of boats for field sampling per fishing week in each subarea, Copper River spring fishery.

Subarea	Fishing week and (sampling hrs) 21 (84)	22 (84)	23 (84)	24 (84)	25 (84)	Subarea totals No. boats	%
West	16	12	9	8	7	52	41
Central	6	8	8	5	7	34	27
East	4	5	8	12	12	41	32
Weekly totals	26	25	25	25	26	127	100

in Table 3, to correspond approximately to the predicted spatial distribution of the weekly catch (cf. Table 1).

The observation time for the sampling team at each boat sampled was estimated as approximately 2.5 hrs. Thus, in each week about 62.5 hrs would be spent in direct one-site observation and about 21.5 hrs in running time between boats. Insofar as possible, sampling would be evenly distributed over the daylight hours and equally distributed between "inside" and "outside" waters, assuming that the fishing effort also would be equally distributed. For practical reasons of distance, time, and mobility, the sampling in the first open fishing period of each week was to begin in the West subarea (nearest Cordova) and end in the East; in the second period, the order would be reversed, ending in the West.

In practice, it was found that it was not possible for one research team to sample one boat per 3.4 hrs of open fishing over the enormous breadth of the Copper River flats, except under optimal conditions. Incessant stormy weather during the 3-week fishery greatly interfered with conduct of the proposed sampling scheme by (a) impeding the progress of the research craft, (b) requiring the team to take shelter more frequently than expected, and (c) impairing visibility, especially during the approximately 5 hrs of twilight each night. During the 192 hrs of sampling time available in the 3-week period, 44 boats were sampled (1/4.4 hrs) instead of the 57 predicted as optimal. The overall proportional distribution of these per subarea was not significantly different from the proportional distribution of the total catch in 1978 (cf. Tables 2 and 4), but the spatial distribution per week was not entirely representative, _if_ catch is proportional to boats. Furthermore, for reasons of safety, most of the sampling was done in inside waters where some shelter from heavy seas was afforded by the barrier bars.

Table 4. Actual number of boats field-sampled per fishing week in each subarea, Copper River spring fishery, 1978.

Subarea	Fishing week and (sampling hrs)			Subarea totals	
	20 (60)	21 (48)	22 (84)	No. boats	%
West	7	4	9	20	45
Central	3	2	12	17	39
East	0	7	0	7	16
Weekly totals	10	13	21	44	100

Basically the same field sampling design was developed for the Coghill fishery, where sampling was begun on June 15, the opening day of the season. This fishery usually is begun as a four-day open period (0600 Monday to 2100 Thursday) per week in June, becoming a five day open period (0600 Monday to 2100 Friday) per week in July. It seldom lasts more than five weeks. A goal of 30 vessels sampled per week was set, and these were to be stratified by subarea on the basis of the historical distribution of the deliveries of salmon to the cannery tenders (Tables 5 and 6). Selection of fishing vessels to be sampled would be based on a table of random numbers, and the sampling was to be distributed as evenly as possible over the daylight hours and over each subarea. The district was divided into three subareas (North, Central, South), corresponding closely to the ADF&G subdistricts (Figure 3).

Table 5. Predicted percentage distribution of weekly deliveries of salmon per subarea, Coghill district (based on 5-year means, 1973-1977, from cannery tender records).

Subarea	Fishing week 25	26	27	28	29	Weekly average
North	34%	25%	24%	30%	30%	29%
Central	19%	18%	8%	8%	7%	10%
South	47%	57%	68%	62%	63%	61%

In 1978, the opening day of the Coghill fishery was Thursday of week 24, rather than Monday of week 25. The area was open to fishing for only 48 hrs in week 24. Weeks 25 and 26 were normal 87-hour (4-day) fishing periods, but in week 27, fishing was closed by ADF&G emergency order for the entire week. Fishing resumed in weeks 28 and 29, with normal 111-hour (5-day) open periods. Because of these changes in timing, the actual distribution of the deliveries by subarea per week differed somewhat from the predicted (cf. Tables 5 and 7).

The field sampling procedure was adjusted in accordance with the changes in timing of the fishery; sampling was conducted during all open

Table 6. Predicted number of boats for field sampling per fishing week in each subarea, Coghill district.

Subarea	Fishing week and (sampling hrs) 25 (87)	26 (87)	27 (111)	28 (111)	29 (111)	Subarea totals No. boats	%
North	10	7	7	9	9	42	28
Central	6	5	2	2	2	17	11
South	14	17	20	19	19	89	60
Weekly totals	30	29	29	30	30	148	99

Table 7. Actual percentage distribution of weekly deliveries of salmon per subarea, Coghill district, 1978 (from cannery tender records).

Subarea	Fishing week 24	25	26	28	29	Weekly average
North	27%	26%	29%	42%	5%	26%
Central	20%	21%	16%	19%	34%	22%
South	53%	53%	55%	39%	61%	52%

fishing periods. Some other on-site modifications were made also to compensate for observed movements of vessels that had not been predicted in the initial planning. It was found that most of the vessels were concentrated in the North, near the Coghill River, in the beginning of each weekly fishing period, then moved to the South later in the week. Hence, sampling was begun each Monday in the North subarea, and progressed southward, terminating near the southern end of Esther Island at the end of each week.

With these modifications, sampling of the Coghill fishery was conducted without any major problems, approximately as proposed. The actual fishing time (sampling time) was somewhat shorter than predicted (total 444 *versus* 507 hrs), hence the number of boats sampled also was somewhat less than predicted (140 *versus* 148) but was a larger proportional sample than proposed. Because of the smaller area and better weather, the research team was able to sample one boat per 3.2 sampling hrs, instead of the predicted one per 3.4 hrs. The distribution of the sample was as shown in Table 8. The sample was distributed about as proposed (cf. Table 6) but somewhat differently than the distribution of the actual deliveries (cf. Table 7).

Table 8. Actual number of boats field-sampled per fishing week in each subarea, Coghill district, 1978.

Subarea	Fishing week and (sampling hrs)					Subarea totals	
	24 (48)	25 (87)	26 (87)	28 (111)	19 (111)	No. boats	%
North	4	11	12	10	10	47	34
Central	2	6	3	3	2	16	11
South	5	15	17	20	20	77	55
Weekly totals	11	32	32	33	32	140	100

Field sampling of the Copper River - Bering River silver salmon fishery was precluded by shortage of operating funds. Only a dockside sample was obtained of this fishery.

Analytical Procedures

Damages inflicted by marine mammals to netted fishes and gear, as reported in the 1977 dockside surveys from the Copper River (spring) fishery, were summarized by week. The overall percentages of harbor seal and Steller sea lion damages to fishes were calculated and applied to the total catch to determine approximate monetary loss (Eq. 1).

Eq. (1)

$$\text{Total monetary loss (fishes)} = \text{Total catch} \times \text{\% marine mammal damaged fishes} \times 7.50^{*}$$

*Average estimated dollar value per fish

The estimated loss of money due to damages inflicted to nets by marine mammals per survey-week was calculated as follows:

Eq. (2)

$$\frac{\text{Value of reported net damage}}{\text{total surveyed catch}} = \frac{x}{\text{total catch (fishery)}}$$

where: x = total monetary value of net damages for the study period

The incidental kills in 1977 for both the spring Copper River fishery and the Coghill fishery were estimated from interviews with 10-15 fishermen randomly encountered on the docks.

While, in the development of the 1978 sample design, the basic units considered were "boats" (field sample) and "fishermen" (dockside sample), these were only the means to facilitate sampling of the total catch of fishes and marine mammals.

The mean percentage of the fishes caught per weekly field and dockside sample that were damaged by marine mammals was taken as the point estimate of damage rate over the fishery as a whole for that week. The 95% confidence limits of these estimates were generated as follows:

Eq. (3)

$$95\% \text{ confidence interval} = \text{mean proportion of fishes damaged} \pm t_{\alpha/2} \cdot sd_w$$

where: $t_{\alpha/2}$ = tabled two-tailed "t" for n-1 degrees of freedom at 95% confidence level

sd_w = weighted standard deviation (Eq. 4) of the percentage of damaged fishes per set of the net (field) or per fisherman's weekly catch (dockside).

The standard deviation in Eq. (3) was weighted according to the number of fishes caught per observation, since the probability of a given fish being damaged by marine mammals was positively correlated with the number of fishes caught in the same observation. For this reason, a binomial variance could not be used. The weighted sample variance was derived by the following equation:

Eq. (4)

$$\text{weighted variance} = \frac{\sum_{i=1}^{n} \pm(p_i - p_x)^2 \; (d_i)1}{\sum_{i=1}^{n} d_i \;\; (n)}$$

where: n is the number of observations
d_i is the number of fishes caught in each observation
p_i is the number of fishes damaged/total fishes in each observation
p_x is the mean number of fishes damaged/total fishes per set of observations

For each of the gillnet fisheries sampled, weekly estimates of damages to nets by marine mammals were developed by species from both the field and the dockside data, as follows:

Eq. (5)

$$\frac{\text{sampled net damage}}{\text{sampled catch}} = \frac{x}{\text{total catch}}$$

where: x is the estimated total net damage

Confidence intervals were not generated since the sample estimates were crude at best and sample variances were extremely large. Thus, the estimated total net damages are presented only as point estimates with very low confidence (± 50% or more).

Estimates of weekly rates of incidental capture and/or kill of marine mammals could be made only from the larger dockside samples (see discussion), utilizing the following equation:

Eq. (6)

$$\frac{\text{reported incidental capture or kill}}{\text{number of vessels sampled}} = \frac{x}{\text{total number of vessels}}$$

where: x is the estimated total number of marine mammals captured and/or killed by the fishery.

Three categories of incidental capture and/or kill were recognized: (1) capture and live release, (2) capture and accidental kill, and (3) direct kill of marine mammals interfering with fishing activities. Average counts per fisherman (by marine mammal species) as well as the variance (not weighted) were computed. Since the rate of incidental catch was very low and the variances were very large, low confidence was indicated in these point estimates (± 50% or more). No confidence intervals were generated.

The probability of differences between weeks, between subareas, and between times of day in amounts of damages to fishes by harbor seals and Steller sea lions, as estimated by the field samples, was tested by the Chi-squared method. The same method was used to test for differences between weeks in the dockside samples. The dockside data, relative to time of day and subarea, could not be analyzed this way, due to poor temporal and geographical resolution (the fishermen were not asked to keep precise records of the time of day and locations where they fished).

For comparison by time of day, the field data were grouped by 6-hr periods (0001-0600, 0601-1200, 1201-1800, 1801-2400). Observations that began in one period and ended in the next were placed in the period in which the greatest part of the observation occurred.

The Chi-squared contingency tables used in this part of the analysis were designed, for example by weeks in the Copper River fishery, as follows:

	week 20	week 21	week 22	Totals
No. of damaged fishes				
No. of undamaged fishes				
Totals				

Caution was indicated when any cell value was less than 5. Significance was discounted if a major contribution was made by cells with such values. When the Chi-squared values were found significant at $\alpha \leq 0.1$, the pairs of columns (e.g. weeks 20 and 21) were compared further. A few comparisons were made also where lower confidence ($\alpha > 0.1$) was indicated; where this was done, the results have been interpreted with due caution. The probability of difference between columns was determined by the test statistic (t), as follows:

Eq. (7)
$$t = \frac{p_1 - p_2}{\sqrt{v_1 + v_2}}$$

where: p_1 is the number of damaged/total fishes in column 1
p_2 is the number of damaged total fishes in column 2
v_1 is the weighted variance for p_1 (Eq. 4)
v_2 is the weighted variance for p_2 (Eq. 4)

When the total number of fishes in either column was less than 31, the critical value for (t) was calculated as follows (Steel and Torrie, 1960):

Eq. (8)
$$\text{new critical t value} = \frac{\frac{s_1^2}{n_1} \cdot t_1 + \frac{s_2^2}{n_2} \cdot t_2}{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}$$

where: s_1^2 is the weighted variance of the first proportion (col. 1)

s_2^2 is the weighted variance of the second proportion (col. 2)
n_1 is the total number of observations of col. 1
n_2 is the total number of observations of col. 2
t_1 is the t value (Eq. 5) for n_1-1
t_2 is the t value (Eq. 5) for n_2-1

The probability of uneven distribution of sample damages over the fishery was examined by the variance ratio (f) test, in which the weighted variance (Eq. 4) of a sample was compared with its variance assuming binomial distribution (Eq. 9):

Eq. (9)

$$\text{binomial variance} = p \cdot q/n$$

where: p is the number of damaged/total fishes for the sample
q is 1 - p
n is the total number of fishes in the sample

The relationship of the number of fishes caught in a given set of the net to the number damaged in the same set was examined by correlation analysis. The same procedure was used in examining the relationship between length of time the net was set and the proportion of fishes damaged in that set. Also examined by this method was the relationship of average weekly catch per fisherman (a measure of abundance of fishes in the fishery) to the rate of damage to fishes by marine mammals for that week.

The fishes damaged by marine mammals were divisible into two categories, salable and unsalable, on the basis of the degree to which they were damaged. "Unsalable" fishes were those damaged to the extent that they were not suitable for any commercial use; "salable" fishes were those slightly damaged but still salvageable, at least in part, for canning. The value of damaged-salable fishes is about 50% less than that of undamaged fishes. The latter bring the higher price per pound, since most of them are marketed as frozen foods.

The estimated dollar value of the damages by marine mammals to the catch was computed using average weight and approximate price per pound of the various species of salmon. These values for salmon in 1978 were as follows:

	Avg. wt.[a]	price/lb	price/avg. fish
King	27.8	1.35	37.50
Red	7.3	1.25	9.10
Silver	9.5	1.05	10.00
Pink	3.6	.39	1.40
Chum	8.7	.40	3.50

[a]Courtesy of Morpac Inc.
(all weights in pounds and prices in dollars)

The estimated dollar cost of repairing damaged nets also was calculated, based on the estimate of $1.50 per square foot, on the average, to repair net damage.

RESULTS

Pilot Study (1977)

In the 19 dockside surveys taken over 3 weeks of the spring Copper River salmon gillnet fishery (22 May-11 June), 8.3% of the catch was reported damaged by marine mammals (includes both salable and unsalable fishes). Harbor seals were indicated as the cause of damages to 2.2% of the catch and the remaining 6.1% damage was attributed to Steller sea lions. Gear damage estimates amounted to an additional 2.3% ($72,086) of the estimated gross value of the catch during the study period (Table 9).

Table 9. Summary of dockside survey data from 1977 pilot study with estimations of monetary losses for three weeks of the spring Copper River gillnet fishery.

Date	Total catch (fishery)	Surveyed catch	# seals damaged	# sea lions damaged	Gear damage
May 22-28	177,664	1636 ($12,270)[a]	75 (58%) 4.6	55-65 (43%)	$320 (3% of gross)
May 29-June 4	121,665	3834 ($28,755)[a]	63 (17%) 1.6	299-329 (83%)	$865 (3% of gross)
June 5-11	70,342	1165 ($ 8,738)[a]	5 (8%) 0.4	55 (92%)	$ 92 (1% of gross)
June 12-19	10,647 (Bering River only)	1385 ($10,388)[a]	20 (100%)1.4	0	$ 70
CUM (Bering River Excluded)					
May 22-June 11	369,571	6635 ($49,763)[a]	26%	74%	$1,277 (2.6% of gross)

Total damaged unsalable fish (surveyed) = 552 (8.3% of total catch surveyed)

Extrapolated to entire fishery = 30,683 damaged, unsalable fish = approx. $230,122
(for period May 22-June 11) = approx. $517 per boat (± 445 boats)

Net damage extrapolated to entire fishery = approx. $72,086
(for period May 22-June 11) = approx. $162 per boat

All species of fish are lumped (approx. 95% are red salmon). Average value estimated at $7.50 per fish.

Catch figures courtesy of the Alaska Department of Fish and Game, Cordova, Alaska.

[a]Approximate gross value of surveyed catch.

Incidental capture and/or kill estimates for marine mammals interacting with the spring Copper River and Coghill fisheries in 1977 are given in Table 10.

Table 10. Estimates of incidental capture and/or kill and direct kill of marine mammals interfering with fishing activities for the Copper River (spring) and Coghill fisheries in 1977 (total number of animals).

Condition	Mammal[a]	Fishery: Copper River (spring)	Fishery: Coghill
Captured/ released alive	HP	45	10
	DP	5[b]	10[b]
	SO	10	?
Captured/ found dead	HP	30	?
	DP	?	?
Directly killed	HS	40-50	15-20
	SL	40-50	10

[a]HP = harbor porpoise, DP = Dall porpoise, SO = sea otter, HS = harbor seal, SL = sea lion

[b]probably 50% drown before release

Copper River Spring Fishery (1978)

Field work in 1978 was begun on 9 May, when a week-long survey of the Copper River delta was made via the R/V *Montague*, a research vessel operated by the Alaska Department of Fish and Game. Purposes of the survey were (1) to determine the location of markers delineating areas open to fishing, (2) to assess the condition of sandbars, entrances, and channels on the delta as regards any changes that might have occurred as a result of winter storms, and (3) to observe the pre-fishing season distribution of harbor seals and Steller sea lions in the area. The vessel track and marine mammal observations are summarized in Figure 10. In general, the numbers of seals and sea lions sighted outside the barrier bars was small, and they were widely scattered. The main concentrations of pinnipeds were in the vicinity of the entrances, and these were mainly harbor seals.

The spring fishing season in 1978 on the Copper River was open only during weeks 20, 21, and 22 instead of for the full five weeks that had been anticipated. The routes traveled each week by the field sampling team in the research vessel, with approximate points of interception of sampled vessels, are indicated in Figures 11 to 13. A total of 44 intercepts were made, at each of which one complete setting, soak, and retrieval of the net was observed. In each such "set", an average of only 8.5 fishes were caught, for a total of 376 fishes examined during the field sampling of this fishery. This amounted to only .17% of the total fishes delivered by the fishery during that period (Table 11). A substantially larger number of boats (91) was sampled in the dockside survey; the sampled catch by those boats amounted to 15,149 fishes or about 6.8% of the total deliveries by the fishery in that period.

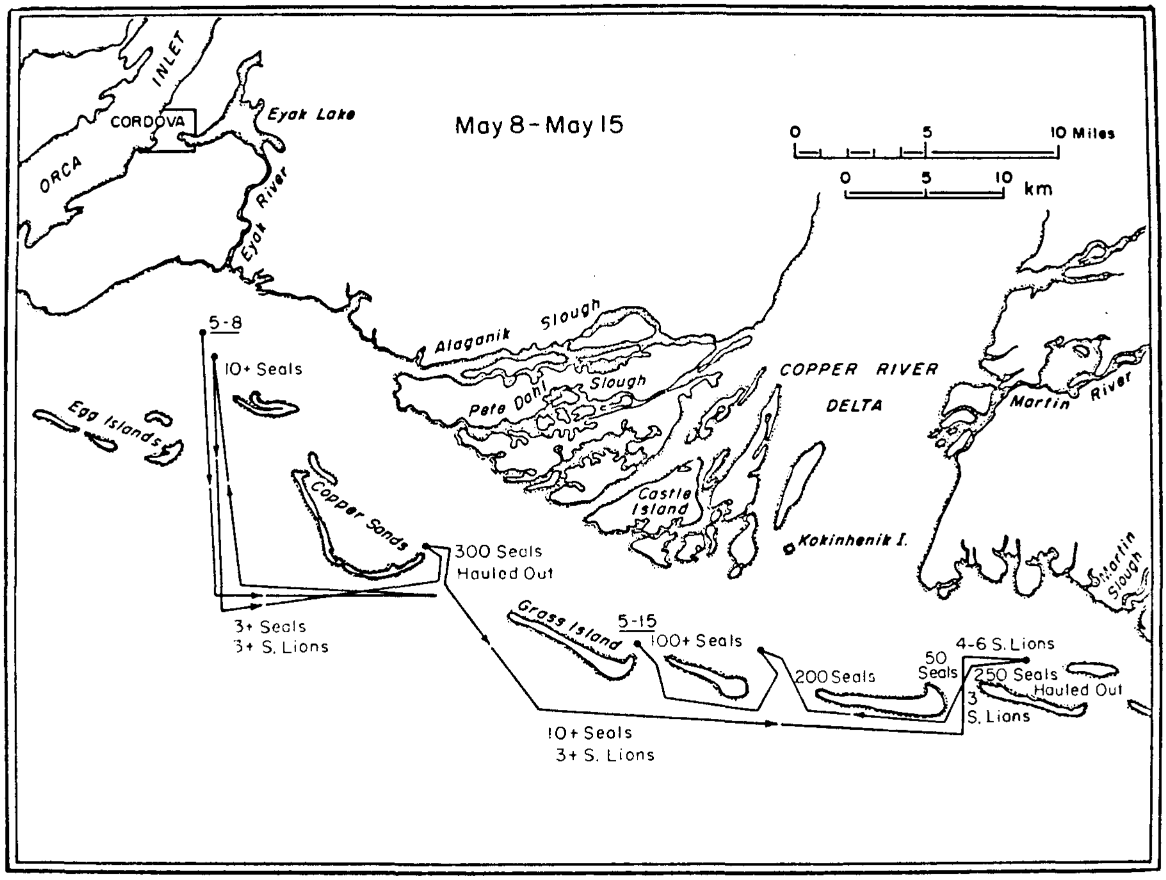

Figure 10. Track of the R/V Montague during boundary-marking cruise, 9-15 May 1978, showing locations and numbers of marine mammals sighted (all were in water, except as indicated).

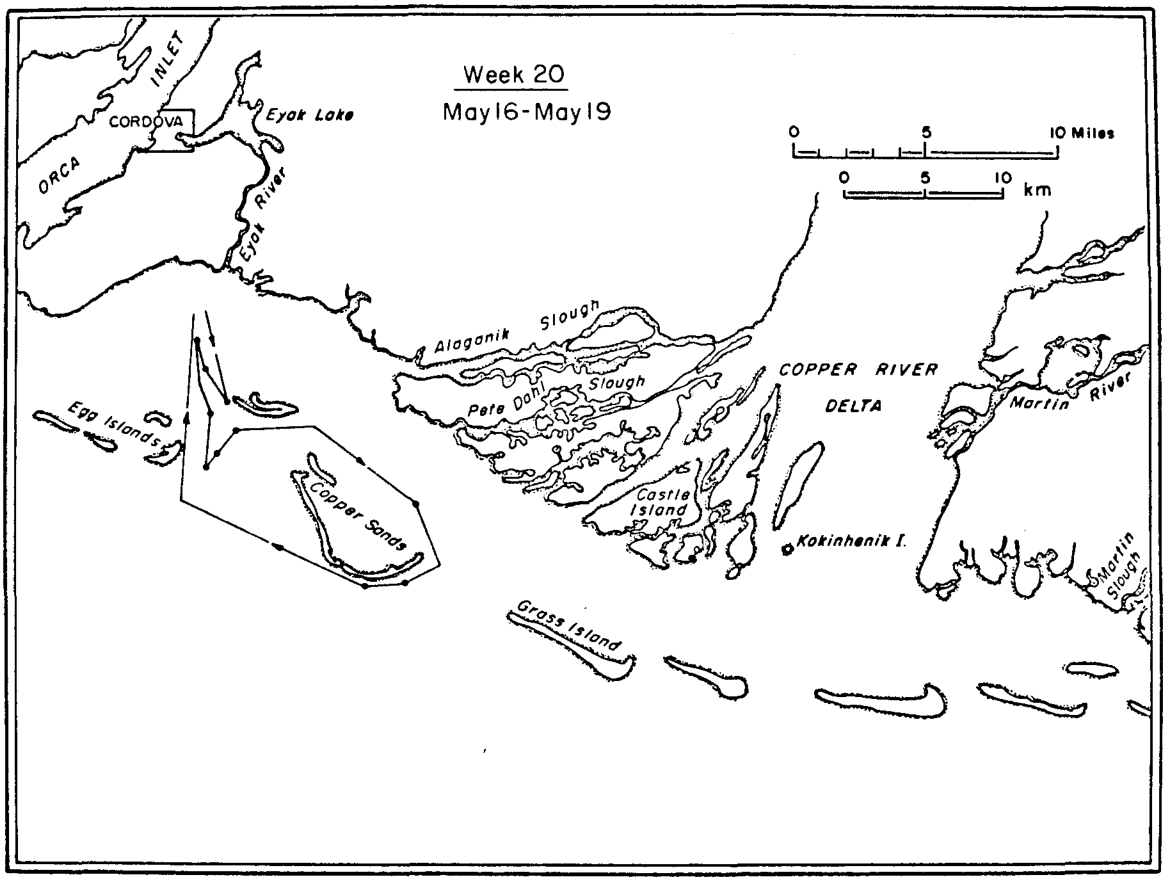

Figure 11. Track of research vessel during week 20, Copper River fishery, showing interceptions (•) of sampled fishing vessels.

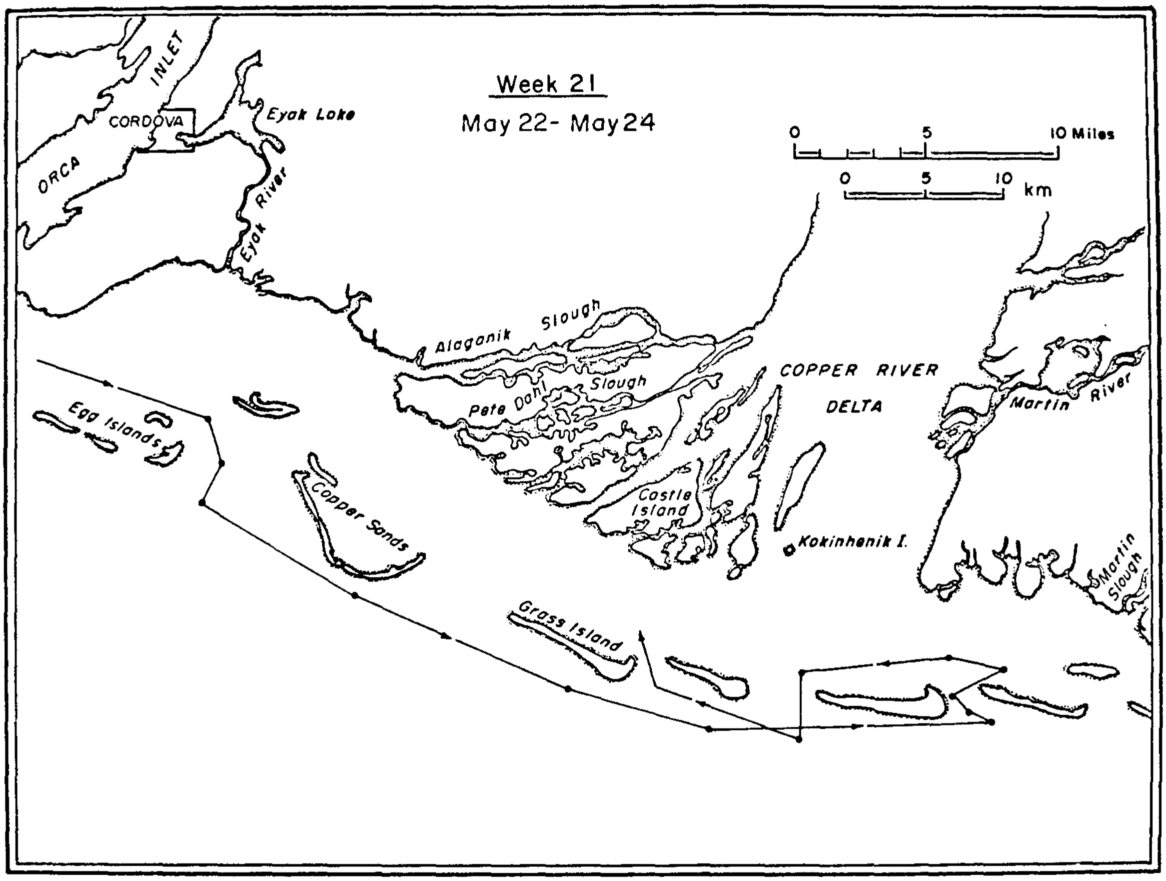

Figure 12. Track of the research vessel during week 21, Copper River fishery, showing interceptions of sampled fishing vessels.

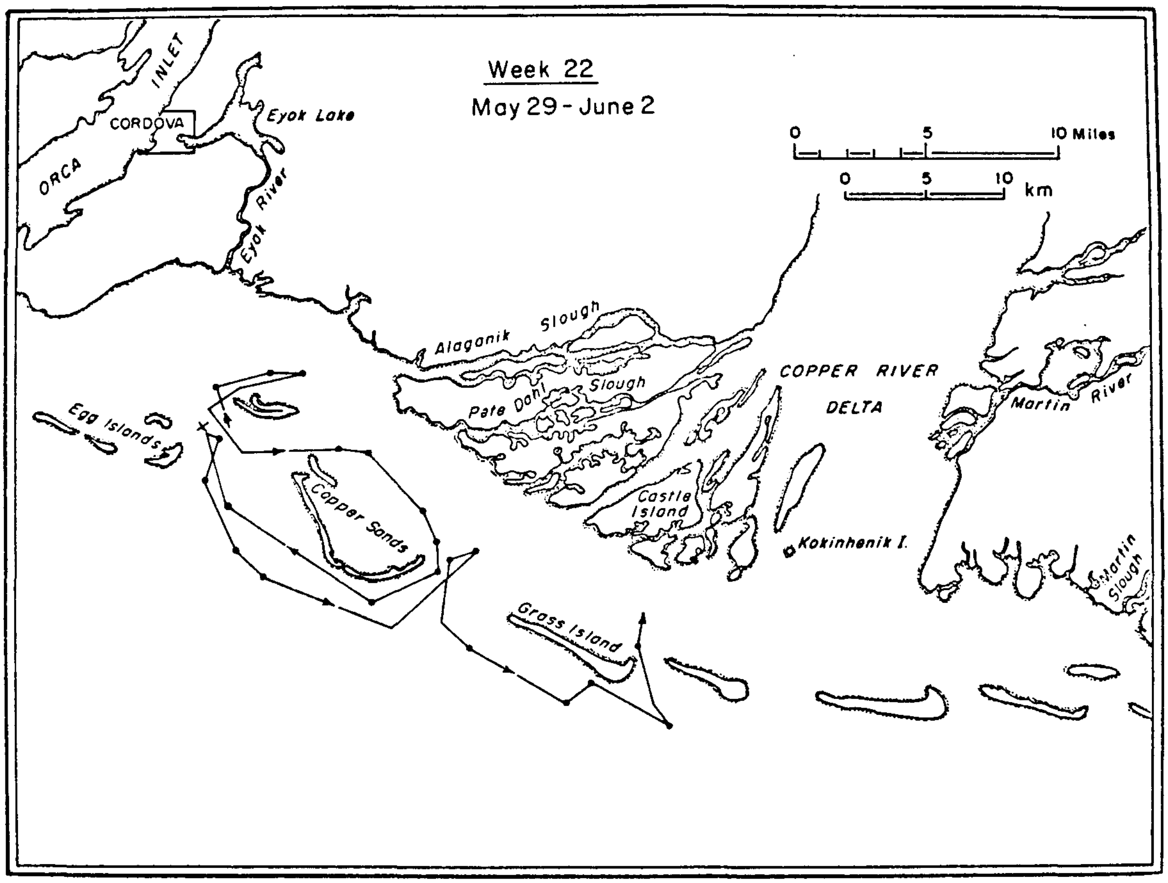

Figure 13. Track of the research vessel during week 22, Copper River fishery, showing interceptions of sampled fishing vessels.

Table 11. Comparison of size of field and dockside samples with weekly totals for the Copper River spring fishery, 1978.

		Fishing week 20	21	22	Totals
Total fishery:	boats	430	437	458	1,325
	fishes delivered	72,787	34,545	114,635	221,967
Field sample:	boats	10	13	21	44
	fishes caught	51	130	195	376
Dockside sample:	boats	31	29	31	91[a]
	fishes caught	4,529	2,278	8,342	15,149

[a]an additional 3 boats declined participation in the study.

Marine mammals were sighted in the vicinity of the net during 10 of the 44 sets observed in the field sample. In 7 cases, these were harbor seals, and in 2 they were sea lions; in 1 case, both were present. In an additional 2 observations, damage to fishes was attributed to marine mammals, although the mammals were not seen. Of the 376 fishes caught by the boats in the field sample, 18 (4.8%) had been damaged in the net by the marine mammals present. In the dockside sample, 485 of the 15,149 fishes caught (3.2%) were reported to have been damaged in the net by marine mammals. The difference between these estimates is not significant. As indicated with greatest confidence by the larger dockside sample, the actual rate of occurrence of damaged fishes in the fishery as a whole probably was between 2.52 and 3.88%. About one-third of these damages were caused by harbor seals and one-half by Steller sea lions; the mammals causing the remainder of the damages could not be identified with certainty. The distribution of damages per week and by species of marine mammal is shown in Table 12.

Table 12. Estimated percentage per week of fishes in the net that were damaged by marine mammals (mean percent per weekly sample ± 95 percent confidence limit), Copper River, spring 1978.

Mammal[a]	Sample	Fishing week 20	21	22	Weekly mean
HS	Field	-	3.08±1.91%	2.05±0.93%	2.12±0.33%
	Dock	1.10±0.40%	0.66±0.24%	1.08±0.38%	1.02±0.21%
SL	Field	-	4.62±3.61%	-	1.59±0.48%
	Dock	1.17±0.13%	4.92±1.79%	1.29±0.49%	1.80±0.39%
UNK	Field	-	2.31±1.43%	0.51±0.23%	1.06±0.33%
	Dock	0.29±0.10%	1.27±0.46%	0.17±0.06%	0.38±0.08%
Weekly total	Field	-	10.01±6.95%	2.56±1.16%	4.77±1.15%
	Dock	2.56±0.63%	6.85±2.49%	2.54±0.93	3.20±0.68%

[a]HS = harbor seal; SL = sea lion; UNK = uncertain (but either harbor seal, sea lion, or both).

Estimated damages to nets by marine mammals were greatest on the Copper River in week 21, when the amount attributed to sea lions was 53,636 feet^2 from the dockside sample and 9,301 feet^2 from the field sample (Table 13). At least part of the difference between these estimates can be attributed to the very conservative approach taken in the field sampling, wherein only the net damages associated with destruction of fishes in the net were recorded; in the dockside sample, the investigator usually was obliged to accept the fishermen's judgment as to the amount and cause of the damages. The greatest amount of net damage by harbor seals took place in week 22, when estimates from field and dockside samples were 1,764 and 2,157 feet^2, respectively. Since the measurements of net damages were crude and the variances of the samples were very large, no confidence limits were generated for these estimates.

In general, those derived from the field sample can be regarded as very conservative; those from the dockside sample probably are more realistic.

Table 13. Point estimates of square feet of net damage attributed to marine mammals per fishing week, Copper River, spring, 1978.

Mammal[a]	Sample	Fishing week 20	21	22	Total (ft^2)
HS	Field	-	-	1,764	1,764
	Dock	466	712	2,157	3,335
SL	Field	-	9,301	-	9,301
	Dock	5,576	52,636	5,744	63,956
UNK	Field	-	-	-	-
	Dock	-	227[b]	5,487	5,714
Weekly total	Field	-	9,301	1,764	11,065
	Dock	6,042	53,575	13,388	73,005

[a]HS = harbor seal; SL = sea lion; UNK = uncertain (but mostly harbor seal, sea lion, or both).

[b]Attributed to sea otter.

The rates of incidental capture and kill of marine mammals during the spring fishery on the Copper River could not be estimated from the field data due to inadequacy of the sample. Estimates derived from the dockside sample (Table 14) suggest that some 300 to 1,000 seals, sea lions, sea otters, and harbor porpoises became entangled in the nets or were shot while interacting with fishing operations. These were about equally distributed in time throughout the three fishing weeks, but the fact that the confidence limits are so wide indicates that the incidence

Table 14. Sample size (n) and estimated total numbers (N) of marine mammals accidentally captured (entangled in nets) that were released alive or found dead, and the number killed directly (shot) while interfering with fishing operations, Copper River, spring 1978. (Based on dockside sample).

		Fishing week						
		20		21		22		
Condition	Mammal[a]	n	N	n	N	n	N	Total N
Captured and released alive:	SO	0	0	3	45	0	0	45
	HP	1	14	1	15	1	15	44
Captured, found dead:	HS	1	14	0	0	7	103	117
	HP	2	28	1	15	1	15	58
Directly killed:	HS	2	28	2	30	1	15	73
	SL	7	97	6	90	8	118	305
Total killed:	HS	3	42	2	30	8	118	190
	SL	7	97	6	90	8	118	305
	HP	2	28	2	30	1	15	58

[a] SO = Sea otter; HP = harbor porpoise; HS = harbor seal; SL = sea lion.

of capture and kill was very unevenly distributed among the fishermen (as was apparent also to the research team on the scene). As might be expected, the species most affected were those to which most of the damages to fishes and gear are attributed, i.e. harbor seals and sea lions. The less offensive mammals (sea otters and harbor porpoises) were released from the nets, whenever possible.

Coghill Summer Fishery (1978)

Fishing in the Coghill district began during the last half of week 24, and field sampling was begun at that time. Since this fishery had not previously been opened so early in recent years, there were no historic delivery data for week 24 on which to base stratification of the sample. Hence, sampling was done on an opportunistic basis in that week, though in accordance with prescribed randomization procedures. Stratified sampling was begun in week 25 and continued in weeks 26, 28, and 29; fishing was temporarily closed during week 27 by ADF&G emergency order. "Dockside" sampling of boats remaining on the fishing grounds was completed at the end of each fishing week.

The routes travelled and approximate points of interception of fishing vessels for field sampling during each week of the fishery are shown in Figures 14 to 18. A total of 140 completed sets of the net were observed, in which the mean number of fishes taken per set was 22.4, i.e. about 2.5 times the number observed in the spring Copper River fishery. Some 3,134 of the caught fishes were examined, amounting to .88% of the total fishes delivered by the fishery (Table 15). The dockside sample comprised 122 boatweeks (8.7% of the total) and 12.9% of the total fishes delivered by the fishery.

Marine mammals were sighted "working the gear" during 36 of the 140 sets observed; in 31 cases, these were harbor seals and in 5 cases they were sea lions. In an additional six observations, damage to fishes by harbor seals was recorded, although the animals were not seen on the gear. Harbor seals also were the major contributors of damages to netted fishes (Table 16). More than four-fifths of the 57 damaged fishes in the field sample and of the 402 in the dockside sample had been affected by harbor seals. The remainder was damaged by sea lions. For the fishery as a whole, percentage estimates of the total fishes damaged

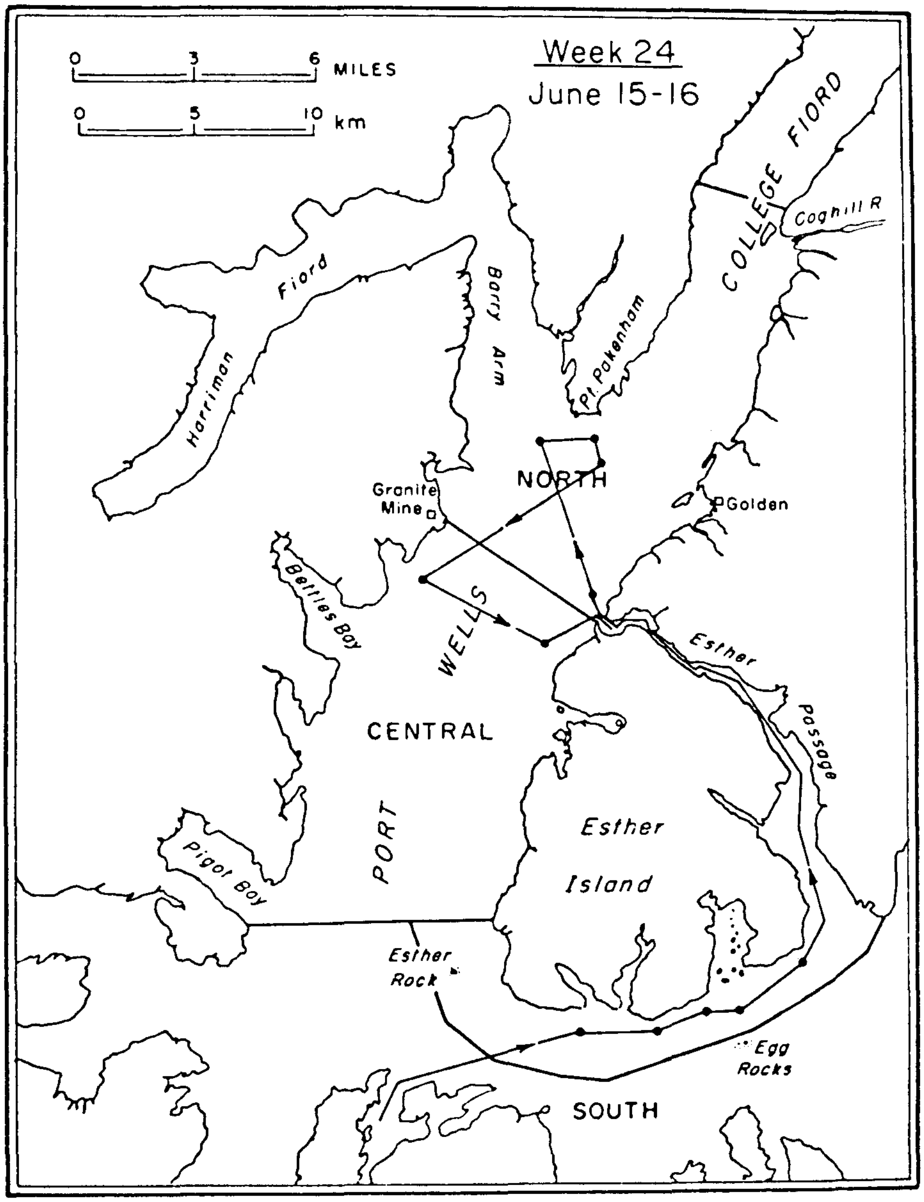

Figure 14. Track of the research vessel during week 24, Coghill fishery, showing interceptions (•) of sampled fishing vessels.

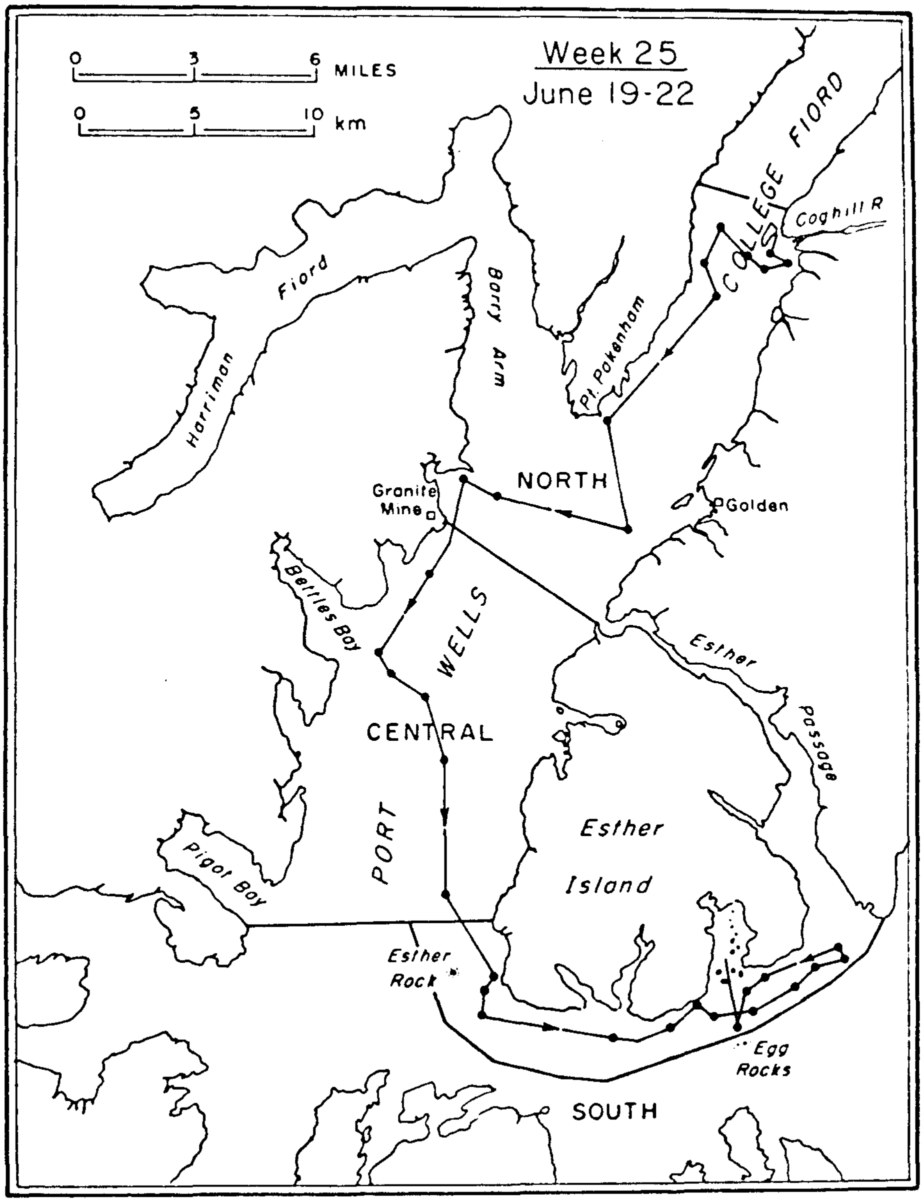

Figure 15. Track of the research vessel during week 25, Coghill fishery, showing interceptions of sampled fishing vessels.

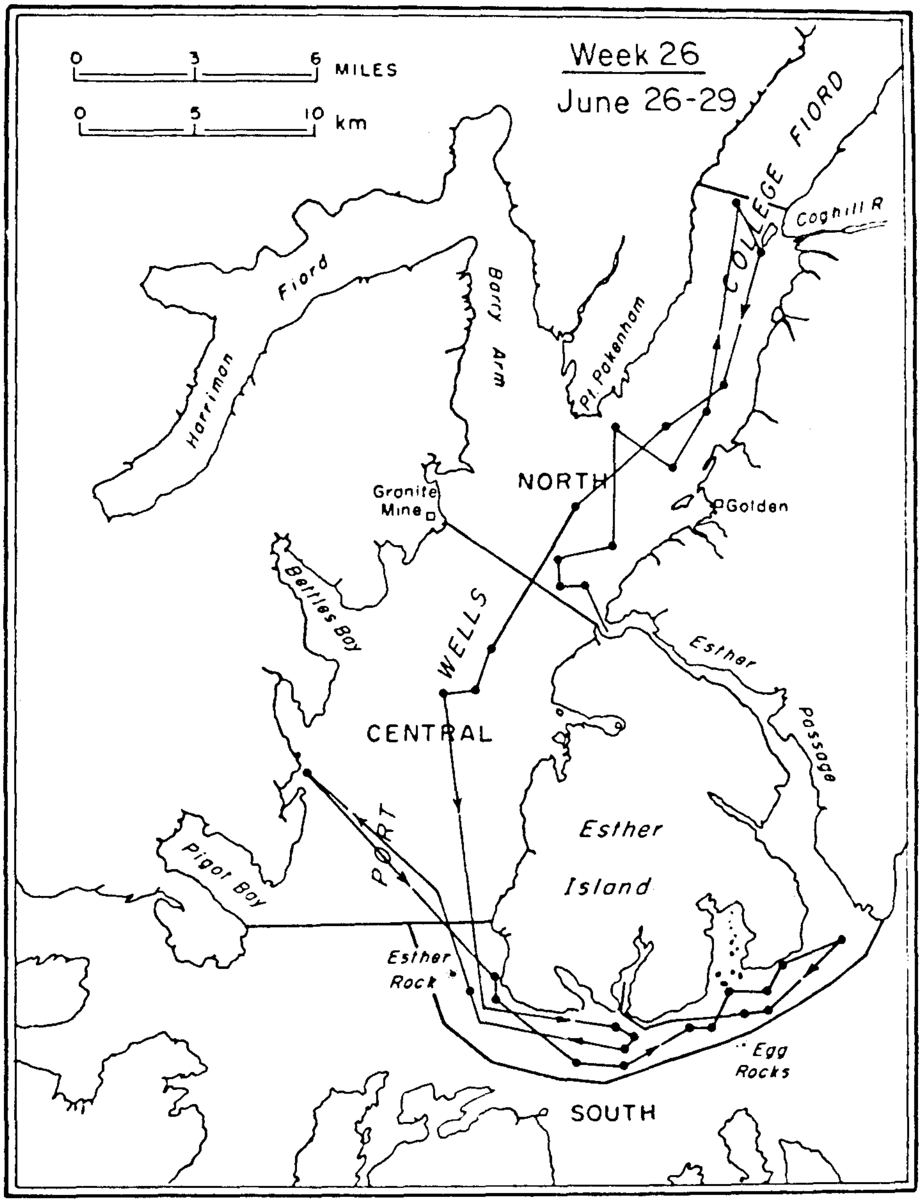

Figure 16. Track of the research vessel during week 26, Coghill fishery showing interceptions of sampled fishing vessels.

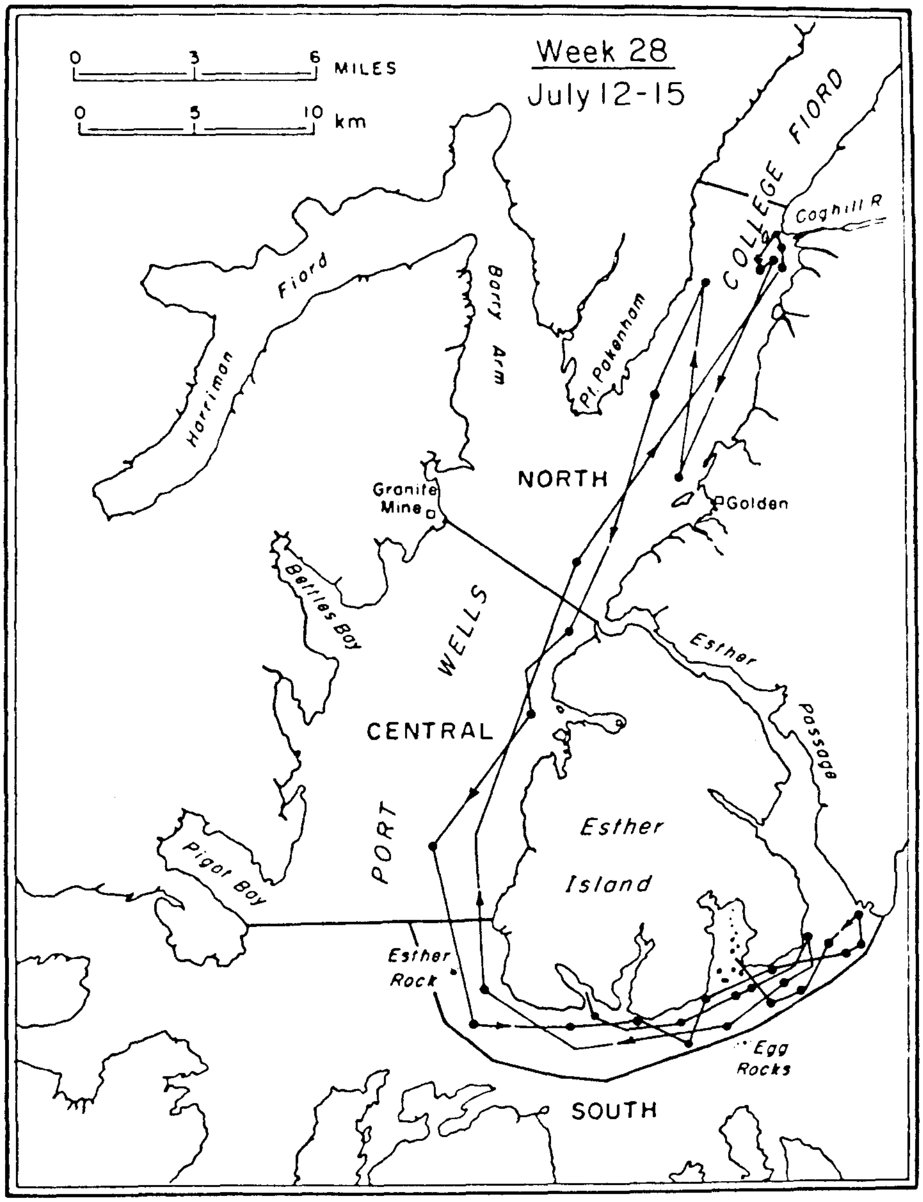

Figure 17. Track of the research vessel during week 28, Coghill fishery, showing interceptions of sampled fishing vessels.

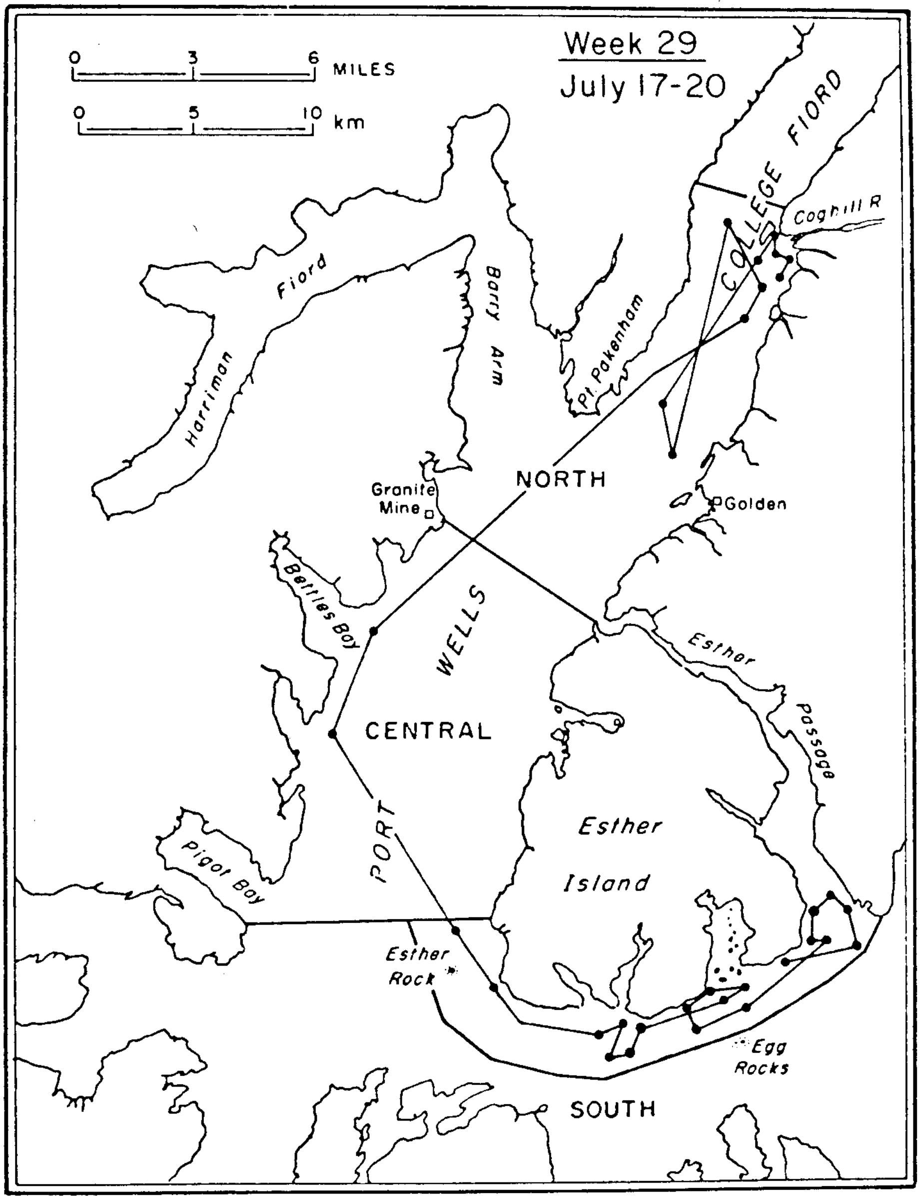

Figure 18. Track of the research vessel during week 29, Coghill fishery, showing interceptions of sampled fishing vessels.

Table 15. Comparison of size of field and dockside samples with weekly totals for the Coghill fishery, 1978.

		Fishing week					
		24	25	26	28	29	Totals
Total fishery:	Boats	251	302	405	260	182	1,400
	Fishes delivered	27,701	68,154	137,532	68,179	53,171	354,737
Field sample:	Boats	11	32	32	33	32	140[a]
	Fishes caught	253	634	1,210	439	598	3,134
Dockside sample:	Boats	15	29	29	31	18	122[a]
	Fishes caught	2,099	8,409	14,557	11,776	8,924	45,765

[a] An additional 2 boats declined participation in the study.

Table 16. Estimated percentage per week of fishes in the net that were damaged by marine mammals (mean % per weekly sample ± 95% confidence limits), Coghill district, 1978.

		Fishing Week					Weekly
Mammal[a]	Sample	24	25	26	28	29	mean
HS	Field	1.58±1.05%	1.89±0.65%	1.49±0.22%	2.51±0.42%	0.84±0.24%	1.60±0.25%
	Dock	0.48±0.26%	0.74±0.27%	0.58±0.23%	1.21±0.42%	0.47±0.27%	0.75±0.14%
SL	Field	0.39±0.26%	-	0.08±0.03%	0.46±0.16%	0.50±0.17%	0.22±0.04%
	Dock	-	0.14±0.05%	0.06±0.05%	0.02±0.02%	0.63±0.28%	0.17±0.09%
Weekly total	Field	1.97±1.31%	1.89±0.65%	1.57±0.25%	2.97±0.58%	1.34±0.41%	1.82±0.29%
	Dock	0.48±0.26%	0.88±0.32%	0.64±0.28%	1.23±0.44%	1.10±0.55%	0.92±0.21%

[a] HS = harbor seal; SL = Steller sea lion.

by marine mammals were 1.53 to 2.11% from the field sample and .71 to 1.13% from the dockside sample. The difference between these estimates is significant but of little consequence, because of the small percentages involved. It is probable that the actual rate was between 1 and 2%, which was only about one-third to one-fourth the rate in the Copper River spring fishery.

Correspondingly lower rates of damages to nets also were observed in the Coghill fishery (Table 17). As in the Copper River fishery, most of the damages by marine mammals were attributed to Steller sea lions, but in this case they appear to have been about evenly distributed in time over the fishery. Salmon sharks (*Lamna ditropis*) were a much more significant cause of net damages here than were marine mammals; point estimates from both the field and the dockside data indicated that some 20 thousand feet^2 of nets were destroyed by these sharks over the fishery as a whole, whereas the total damages by marine mammals probably were no more than 3 to 6 thousand feet^2.

Estimates of incidental capture and release or kill, derived from the dockside sample, suggest that about 250 marine mammals were affected in this fishery, compared to more than 600 in the Copper River fishery. These were mainly harbor seals (Table 18). Unique in this fishery was the incidental catch of Dall porpoises, approximately 40 of which were accidentally entangled in the nets. About three-fourths of these died before they could be released.

Copper-Bering Autumn Fishery (1978)

The Copper River-Bering River autumn silver salmon fishery was

Table 17. Point estimates of square feet of net damage attributed to marine mammals per fishing week, Coghill district, 1978.

Mammal[a]	Sample	Fishing Week					Total (ft^2)
		24	25	26	28	29	
HS	Field	-	-	-	-	178	178
	Dock	-	-	-	417	-	417
SL	Field	2,190	-	2,273	1,553	356	6,372
	Dock	-	324	195	289	506	1,314
UNK	Field	-	-	-	-	-	-
	Dock	-	162[b]	756	-	328	1,246
Weekly total	Field	2,190	-	2,273	1,553	534	6,550
	Dock	-	486	951	706	834	2,977

[a]HS = harbor seal; SL = Steller sea lion; UNK = uncertain (but mostly harbor seal, sea lion, or both).

[b]Attributed to Dall porpoise.

Table 18. Sample size (n) and estimated total numbers (N) of marine mammals accidentally captured (entangled in nets) that were released alive or found dead, and the number killed directly (shot) while interfering with fishing operations, Coghill district, 1978. (Based on dockside sample).

		Fishing week										
		24		25		26		28		29		
Condition	Mammal[a]	n	N	n	N	n	N	n	N	n	N	Total N
Captured and released alive:	HS	0	0	0	0	1	14	0	0	1	10	24
	SL	0	0	0	0	0	0	1	8	0	0	8
	SO	0	0	1	10	0	0	0	0	0	0	10
	DP	0	0	1	10	0	0	0	0	0	0	10
Captured, found dead:	HS	0	0	0	0	0	0	1	8	2	20	28
	SO	0	0	0	0	0	0	0	0	1	10	10
	DP	1	17	0	0	1	14	0	0	0	0	31
Directly killed:	HS	2	33	2	21	2	28	2	17	2	20	119
	SL	0	0	1	10	0	0	0	0	1	10	20
Total killed:	HS	2	33	2	21	2	28	3	25	4	40	147
	SL	0	0	1	10	0	0	0	0	1	10	20
	SO	0	0	0	0	0	0	0	0	1	10	10
	DP	1	17	0	0	1	14	0	0	0	0	31

[a]HS = harbor seal; SL = sea lion; SO = sea otter; DP = Dall porpoise.

officially opened in week 32 (6-12 August), but intensive fishing did not get underway until week 34 (20-26 August). Sampling was conducted during weeks 34 to 36, in which approximately 68% of the total deliveries by the fishermen were made. Only the dockside sample was obtained; field sampling was precluded by shortage of operating funds for the research vessel and by very stormy weather.

The sample of fishes caught was about 11.8% of the deliveries during the 3-week period sampled by the dockside method; this amounted to 8% of the total deliveries by the fishery over its 7-week duration. The distribution of the sampling, in relation to boat and delivery statistics of the fishery, is shown in Table 19.

Table 19. Comparison of size of dockside samples with weekly totals for the Copper-Bering autumn fishery, during the weeks of heaviest fishing, 1978.

		Fishing week			
		34	35	36	Totals
Total fishery:	boats	310	331	340	981
	fishes delivered	39,719	79,184	89,973	208,876
Dockside sample:	boats	28	30	30	88[a]
	fishes caught	4,924	7,971	11,708	24,603

[a]one additional boat declined participation in the study.

According to the fishermen's reports, sea lions were absent from the Copper and Bering River deltas during the course of the fishery. However, harbor seals were abundant and were identified as the cause of nearly all of the damages incurred (Table 20). Reports of damage rates to netted fishes and to the nets themselves (Table 21) increased weekly, over the three weeks of the survey. Paradoxically, the incidental kill of harbor seals seems to have declined steadily during that time (Table 22), probably due to decreasing daylength and increasing wariness of the seals during the fishery. Fishermen reported that a majority of depredations occurred during hours of darkness.

Table 20. Estimated percentage per week of fishes in the net that were damaged by marine mammals (mean percent per weekly sample ± 95 percent confidence limits), Copper-Bering fishery (dockside sample), autumn 1978.

Mammal[a]	Fishing week 34	35	36	Weekly mean
HS	1.71±0.68%	2.77±1.07%	4.15±1.60%	3.21±0.68%
SL	-	-	-	-
UNK	0.20±0.08%	-	0.10±0.04%	0.08±0.04%
Weekly total	1.91±0.76%	2.77±1.07%	4.25±1.64%	3.29±0.72%

[a]HS = harbor seal, SL = sea lion, UNK = uncertain (probably harbor seal).

Table 21. Point estimates of square feet of net damage attributed to marine mammals per fishing week, Copper-Bering fishery (dockside sample), autumn 1978.

Mammal[a]	Fishing week 34	35	36	Total (ft^2)
HS	81	159	1,783	2,023
SL	-	-	-	-
Weekly total	81	159	1,783	2,023

[a]HS = harbor seal; SL = sea lion.

Table 22. Sample size (n) and estimated total numbers (N) of marine mammals accidentally captured (entangled in nets) that were released alive or found dead, and the number killed directly (shot) while interfering with fishing operations, Copper-Bering fishery (dockside sample), autumn 1978.

		Fishing week						
		34		35		36		
Condition	Mammal[a]	n	N	n	N	n	N	Total N
Captured and released alive:	HS	0	0	2	22	1	11	33
	SO	1	11	0	0	0	0	11
Captured, found dead:	HS	0	0	0	0	1	11	11
Directly killed:	HS	5	55	4	44	1	11	111
Total killed:	HS	5	55	4	44	2	23	122

[a]HS = harbor seal; SO = sea otter.

Relationships of Damage Rates

That the rate of damages to fishes in the nets was not uniform in either space or time in any of the fisheries was suggested by the findings of the 1977 pilot study. Hence, the probability of non-uniformity in the 1978 data was tested, using the field and dockside samples. This was done by the Chi-squared method. The results (Table 23) may be summarized, as follows:

1. Damages by harbor seals probably were uniformly distributed by subareas in the spring Copper River fishery, but there is less than 0.1% probability that they were uniformly distributed in the Coghill fishery.

2. Damage rates per week by harbor seals probably were uniform in the Copper River spring fishery, but the dockside samples indicate a very low probability (<0.001%) of their being uniform in either the Coghill or the Copper-Bering fisheries.

Table 23. Comparison of the ratios of damaged/undamaged (by marine mammals) fishes in subarea, weekly and hourly subsamples for evidence of non-random distribution in each fishery (Chi-squared method).

Fishery	Sample	Rates compared	Mammal[a]	X^2	d.f.	Probability of uniformity
Copper River	Field	Subareas	HS	4.5	5	>.25
			SL	6.3	5	>.25
		Weeks	HS	1.6	2	>.25
			SL	12.1	2	<.005
	Dockside	Weeks	HS	3.5	2	>.1
			SL	144.8	2	<.001
Coghill	Field	Subareas	HS	21.8	2	<.001
			SL	4.5	2	>.1
		Weeks	HS	5.0	4	>.25
			SL	5.9	4	>.1
	Dockside	Weeks	HS	51.5	4	<.001
			SL	138.0	4	<.001
Copper-Bering	Dockside	Weeks	HS	73.9	2	<.001
Copper-Coghill	Field	Time[b]	HS+SL	22.9	3	<.001

[a]HS = harbor seal; SL = sea lion.

[b]Time periods: 0001-0600, 0601-1200, 1201-1800, 1801-2400.

3. Damages by sea lions per subarea probably were uniform in distribution both in the Copper River and in the Coghill fisheries.

4. It is highly improbable that the weekly rates of damage by sea lions were uniform in either the Copper River or the Coghill fisheries (dockside $p < 0.005$, $< 0.001\%$, respectively).

5. Damages by seals and sea lions (combined) probably were not uniformly distributed in relation to time of day ($p < 0.001\%$), judging from the combined field sample data from the Copper River and Coghill fisheries.

The first of these findings is suspect because of the small size of the field subsamples from the Copper River fishery (Table 24). Taken more realistically, by examining the data from the dockside sample, it is strongly suggested that the rate of damage by all marine mammals was greater in the Central sub-area than in the East or West (Table 25). The dockside sample probably was biased toward the West (see Discussion). Both the field and dockside data suggested that damages caused by sea lions took place mostly in outside waters, while those by harbor seals were about evenly distributed between inside and outside sectors.

In the Coghill fishery, the rate of occurrence of fishes damaged by harbor seals was very significantly higher in the North than in the South; damages by sea lions were greater in the South than in the North (Table 26). This pattern was also strongly suggested by the dockside data.

Table 24. Subsample distribution of damages by harbor seals and sea lions per subarea in field data for the Copper River and Coghill fisheries, 1978.

			Subarea					
	Class of		West		Central		East	
Fishery	fishes	Mammal[a]	Inside	Outside	Inside	Outside	Inside	Outside
Copper River	Damaged	by HS	1	0	1	6	0	0
		by SL	0	0	0	5	1	0
		by UNK	0	4	0	0	0	0
	Undamaged		104	36	46	150	23	3
			North		Central		South	
Coghill	Damaged	by HS	41		2		7	
		by SL	1		0		6	
	Undamaged		1508		138		1424	

[a]HS = harbor seal, SL = sea lion, UNK = marine mammal, unidentified.

Table 25. Subsample distribution of percentage of total reported damaged fishes by harbor seals and sea lions per subarea from dockside data for the Copper River (spring), the Coghill, and Copper-Bering River (autumn) fisheries, 1978[a].

Fishery	Mammal[c]	Subarea						
		West		Central		East		Not
		Inside	Outside	Inside	Outside	Inside	Outside	assignable[b]
Copper River (spring)	HS	18	18	33	29	2	0	0
	SL	0	19	0	72	2	0	8
		North		Central		South		Not assignable[b]
Coghill	HS	51		5		38		6
	SL	0		1		99		0
		West		Central	East	Bering River		Not assignable[b]
Copper-Bering River (autumn)	HS	26		0	7	59		8

[a]Damages to fishes assigned to subarea by major locality of marine mammal damages as reported by the fisherman.

[b]Some damaged fishes could not be assigned to a subarea because of lack of resolution in dockside data.

[c]HS = harbor seal; SL = Steller sea lion.

Table 26. Probability of difference between subareas in rate of damages to fishes by harbor seals (HS) and sea lions (SL), Coghill district, 1978. (t values).

		North	Central
Central	(HS)	0.73	-
	(SL)	6.4[a]	-
South	(HS)	2.1[a]	0.78
	(SL)	7.8[a]	9.2[a]

[a]Significantly different ($p < 0.05$)

Since no field data were available for the fall Copper River-Bering River fishery, the only indications of comparative location of damages were from the dockside data, which were not sufficiently detailed for analysis. However, they suggested that the greatest damages were sustained in the Bering River district.

In both the field and the dockside samples from the Copper River spring fishery, the proportion of fishes damaged by sea lions was greatest in week 21, the second week of the season (Figure 19). This difference was significant (Table 27). Damages by harbor seals, measured best by the dockside sample, did not differ significantly between weeks (Figure 20).

Table 27. Comparison by weeks of damage rates to fishes in the net by sea lions, Copper River, spring 1978. (t values).

	Week 20		Week 21	
	Field	Dock	Field	Dock
Week 21	3.27[a]	4.04[a]	-	-
Week 22	0	0.71	3.27[a]	3.74[a]

[a]Significantly different ($p < 0.05$)

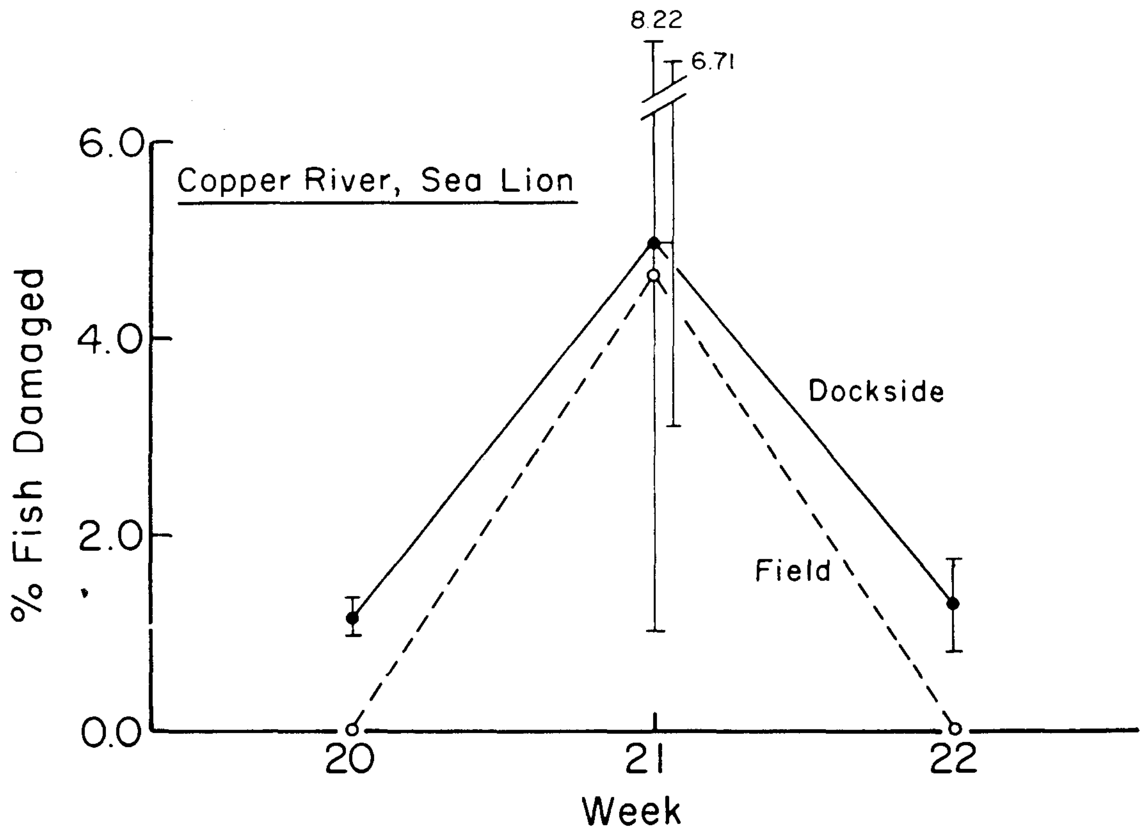

Figure 19. Estimated damage rates to netted fishes by sea lions per week, Copper River, spring, 1978, with 95% confidence limits.

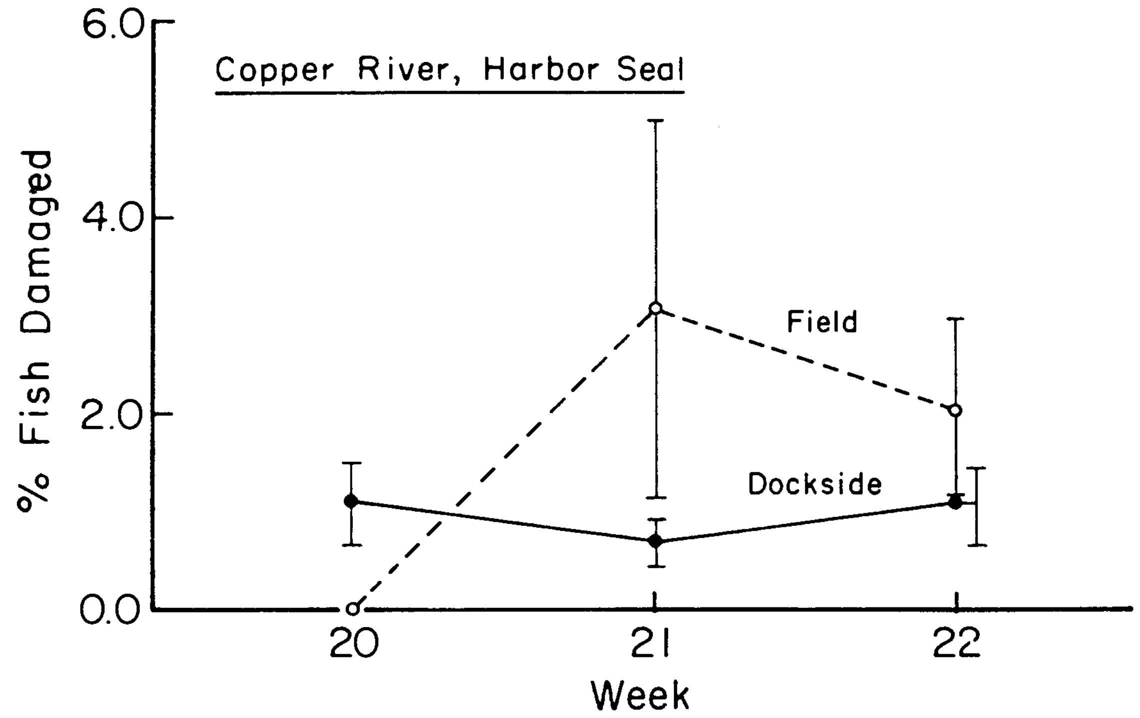

Figure 20. Estimated damage rates to netted fishes by harbor seals per week, Copper River, spring, 1978, with 95% confidence limits.

In the Coghill fishery, damages by harbor seals occurred at about the same rates in all weeks, except week 28 (Figure 21), in which they were significantly higher (Table 29). Damage rates by sea lions in this fishery appear to have been much more erratic (Figure 22). However, this is to some extent a function of their low rate of occurrence and poor representation both in the field and in the dockside samples. Because of the small size of the subsamples, the calculated "t" values are suspect (Table 25). It seems probable that the observed rate of damages was significantly higher only in week 29, and that it was otherwise uniformly low in weeks 24 to 28.

Only harbor seals were implicated as the cause of damages to netted fishes in the autumn fishery on the Copper and Bering River deltas. The rate of occurrence of such damages showed a trend of continuous increase during the three weeks sampled (Figure 23), in which the rate in week 36 was significantly higher than in week 34 (Table 28).

Table 28. Comparison by weeks of damage rates to fishes in the net by harbor seals (dockside data only), Copper-Bering fishery, autumn 1978. (t values).

	Week 34	Week 35
Week 35	1.78	-
Week 36	2.98[a]	1.50

[a]Significantly different ($p < 0.05$)

The combined field data from the Copper River and Coghill fisheries were examined further for evidence of some daily pattern in time of the occurrence of damages by marine mammals to netted fishes (Table 30). This analysis has indicated that the observed rates were significantly

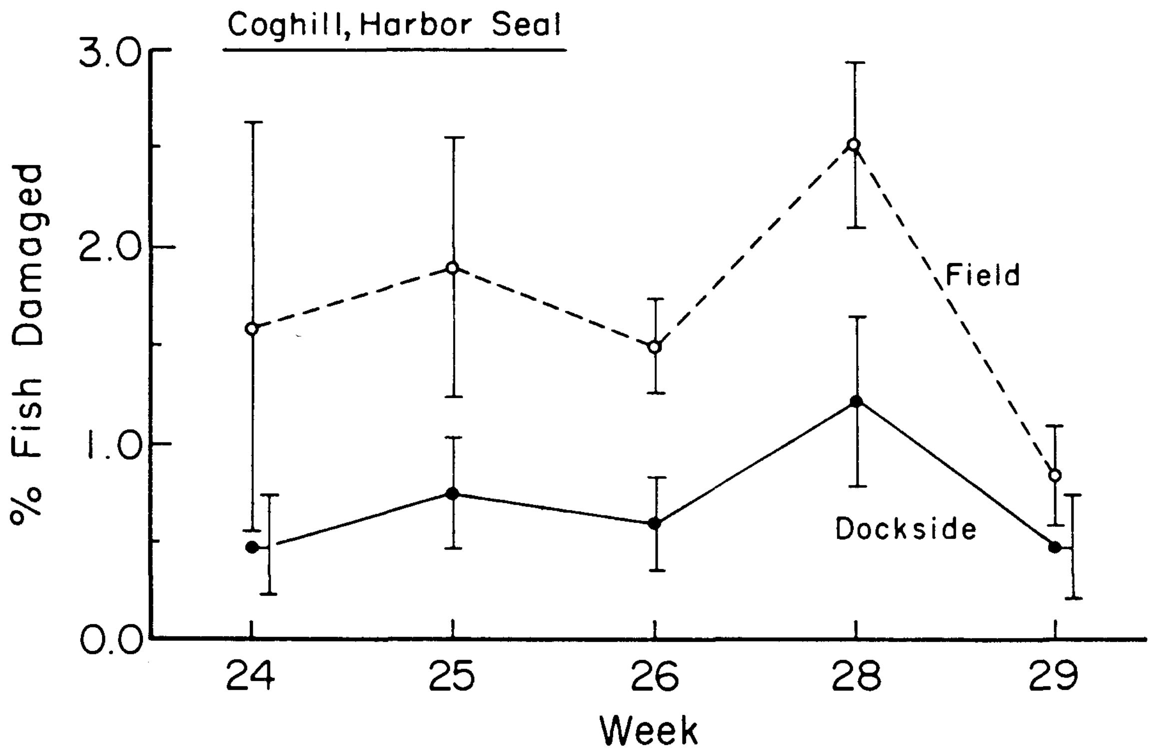

Figure 21. Estimated damage rates to netted fishes by harbor seals per week, Coghill district, 1978, with 95% confidence limits.

Table 29. Comparison by weeks of damage rates to fishes in the net by harbor seals (HS) and sea lions (SL), Coghill district, 1978. (t values).

		Week 24		Week 25		Week 26		Week 28	
Week	Mammal	Field	Dock	Field	Dock	Field	Dock	Field	Dock
25	HS	0.54	1.42	-	-	-	-	-	-
	SL	3.29[a]	4.80[a]	-	-	-	-	-	-
26	HS	0.19	0.66	1.15	0.87	-	-	-	-
	SL	2.60[a]	2.00	5.80[a]	1.84	-	-	-	-
28	HS	1.43	2.90[a]	1.12	1.82	2.30[a]	2.56[a]	-	-
	SL	0.44	1.60	5.90[a]	4.20[a]	4.40[a]	3.33[a]	-	-
29	HS	1.49	0.03	2.89[a]	1.42	3.54[a]	0.68	3.60[a]	2.93[a]
	SL	0.71	4.30[a]	5.60[a]	3.13[a]	4.90[a]	3.73[a]	0.39	4.15[a]

[a]Significantly different ($p < 0.05$)

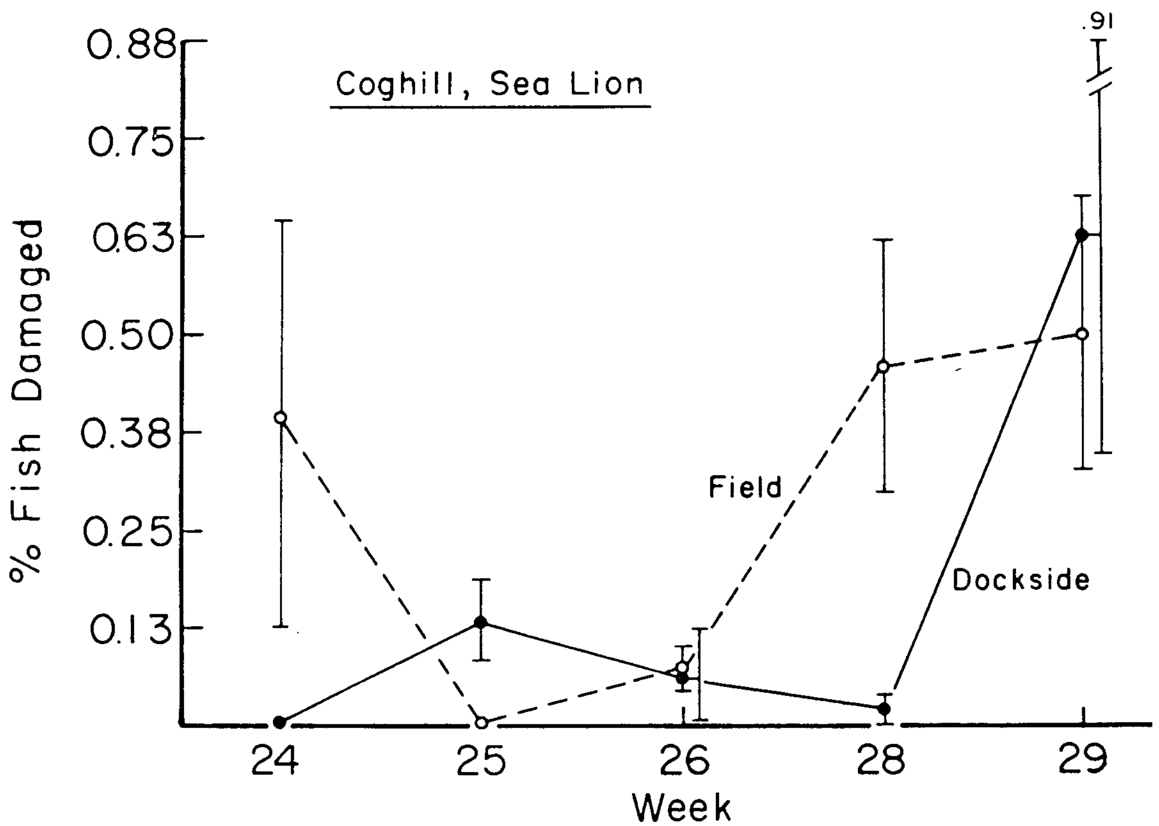

Figure 22. Estimated damage rates to netted fishes by sea lions per week, Coghill district, 1978, with 95% confidence limits.

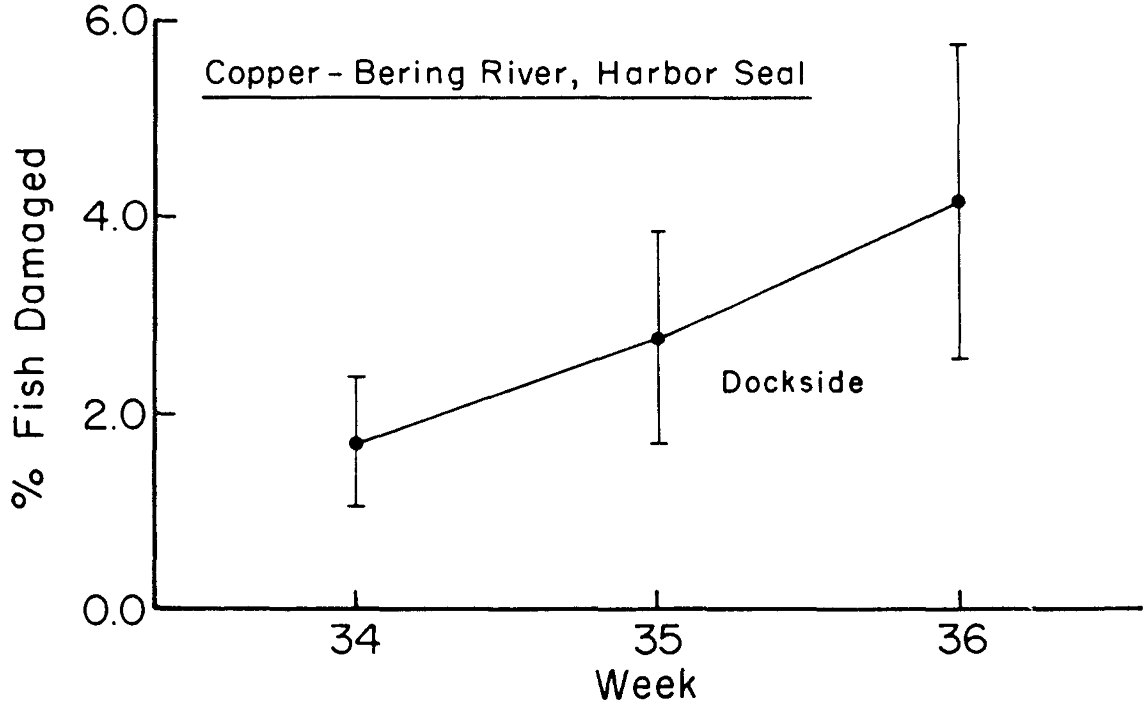

Figure 23. Estimated damage rates to netted fishes by harbor seals per week, Copper-Bering deltas, autumn, 1978, showing 95% confidence limits.

Table 30. Comparison of damage rates to fishes in the net by all marine mammals per daily time period, from combined field samples, Copper River and Coghill fisheries, 1978. (t values).

Time	No. of boats (sets) sampled	Percent of fishes damaged	Time (hrs)		
			0001-0600	0601-1200	1201-1800
0001-0600	5	6.20±5.90	-	-	-
0601-1200	78	1.93±0.36	1.54	-	-
1201-1800	79	3.30±0.20	1.02	2.10[a]	-
1801-2400	21	0.35±0.13	2.11	6.79[a]	7.78[a]

[a]Significantly different ($p < 0.05$)

lower in the evening (1800 to 2400 hrs) than at any other time of day, and suggests that the highest rates may have been in the early morning and afternoon (especially the latter).

In the field samples from the Copper River and Coghill fisheries, all of the damage by marine mammals to netted fishes took place in only about 30% of the observed sets. Similarly, in the larger dockside samples for those fisheries, 30% of the fishermen interviewed had suffered nearly 80% of the total damages. This suggests that damages tend not to be evenly distributed over the fishery (as indicated also by the foregoing), but to be clustered in particular groups of fishermen, probably as a consequence of their choice of fishing techniques and locations. The probability that the damages really were unevenly distributed among the fishermen was tested by comparison of binomial and weighted variances of the rate of damage per set (field data) and per fisherman (dockside data) in 23 subsamples of sufficient size for analysis. The results (Table 31) indicate that, in 18 of the 23 subsamples tested, the null hypothesis was not upheld, i.e. that the observed tendency for clustering probably was real.

The percentage of fishes damaged by harbor seals per boat/week was positively correlated ($r = .85$, $p < 0.05$) with the number of fishes caught per boat/week in the dockside data from the spring Copper River in 1977 and 1978 and autumn Copper-Bering River fisheries in 1978 (Figure 24). This relationship did not hold in the Coghill fishery. No comparable correlation could be demonstrated between rates by sea lions and catch.

Table 31. Comparison of binomial and weighted variances (variance ratio "f-test") by subsamples of rates of damages to fishes per set of the net (field) and per fisherman (dockside).

Fishery	Sample	Subsample[a]	d.f. numerator/ denominator	Variance ratio (f-value)
Copper (spring)	Field	SL/Central-outside	9/ 16	.518
		SL/East-inside	5/ 24	.174[b]
	Dock	SL/Week 20	30/ 4529	1.76[b]
		SL/Week 21	29/ 2278	4.07[b]
		SL/Week 22	30/ 8342	3.94[b]
Coghill	Field	SL/North	46/ 1549	.250[b]
		SL/South	76/ 1436	.785
		HS/North	46/ 1549	6.04[b]
		HS/Central	14/ 139	1.59
		HS/South	76/ 1436	1.27
		HS/Week 24	10/ 252	.369[b]
		HS/Week 25	31/ 633	.383[b]
		HS/Week 26	31/ 1209	.099[b]
		HS/Week 28	32/ 438	.342[b]
		HS/Week 29	31/ 597	.158[b]
	Dock	HS/Week 24	14/ 2099	.680
		HS/Week 25	28/ 8409	2.38[b]
		HS/Week 26	27/14557	4.00[b]
		HS/Week 28	30/11776	4.70[b]
		HS/Week 29	17/ 8924	.158[b]
Copper-Bering	Dock	HS/Week 34	27/ 4924	3.05[b]
		HS/Week 35	29/ 7971	7.75[b]
		HS/Week 36	29/11708	17.40[b]

[a]HS = harbor seal; SL = sea lion.

[b]Significantly different ($p < 0.05$)

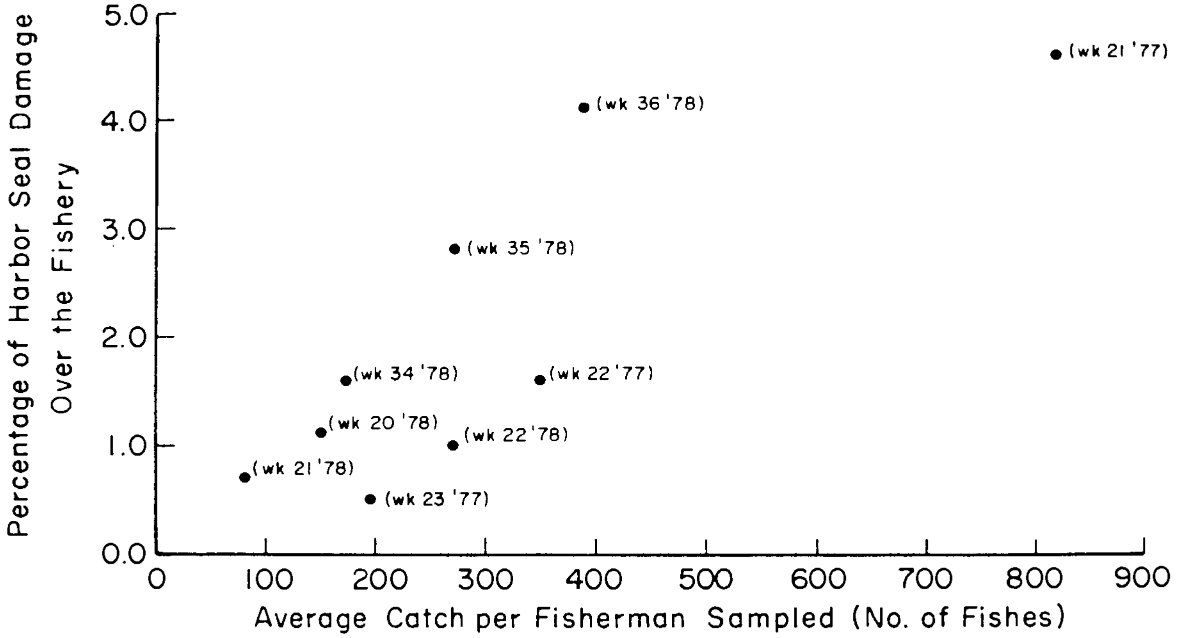

Figure 24. Relationship of mean weekly catch per fisherman to percentage of fishes damaged by harbor seals, Copper River spring 1977 and 1978 and Copper-Bering autumn 1978.

The number of fishes caught per set of the net and the proportion of them that was damaged by all marine mammals (field data) also were positively correlated in the Copper River ($r = 0.33$, $p < 0.05$) and Coghill ($r = 0.35$, $p < 0.01$) fisheries. In addition, there was a weak positive correlation between the length (hrs and mins duration) of the set and the percentage of fishes damaged in both the Copper River ($r = 0.25$, $p = 0.1$) and the Coghill ($r = 0.23$, $p < 0.01$) fisheries.

Financial Loss from Damages by and to Marine Mammals

For the fishermen, the ultimate consequences of their interactions with marine mammals are (1) the loss of potential income, due to reduced or zero value of fishes damaged, and (2) increased overhead expenses, due to destruction of their nets. Many recognize also the further loss of potential income from the marine mammals accidentally and intentionally killed. In determining these losses, we accepted the dockside samples as the better estimators (i.e. with greater confidence) and rejected the field samples.

A large proportion of the fishes sampled were undamaged and readily marketable. Of those that were damaged by marine mammals, some could be sold ("salable") while others were unfit for commerce ("unsalable"). Using the numbers recorded in the dockside samples, and given the actual numbers of fishes sold to the processors, point estimates of total catch, undamaged fishes, and damaged (salable and unsalable) fishes were generated for each fishery as a whole (Table 32).

The potential gross dollar value to the fishermen that participated in the Copper River, Coghill, and Copper-Bering River salmon gillnet

Table 32. Point estimates ("fishery") of total catch and numbers of damaged fishes, based on dockside ("sample") data, Copper River, Coghill and Copper-Bering salmon gillnet fisheries, 1978.

District	Data	Total catch	Undamaged	Damaged		Deliveries[a]
				Salable	Unsalable	
Copper River	Sample	15,149	14,664	120	365	14,784
	Fishery	295,386	285,929	2,340	7,117	288,269
Coghill	Sample	45,765	45,344	179	242	45,523
	Fishery	356,623	353,342	1,395	1,886	354,737
Copper-Bering	Sample	24,603	23,794	239	570	24,033
	Fishery	314,456	304,116	3,055	7,285	307,171

[a]Undamaged + salable damaged.

fisheries in 1978 was about 9 million dollars. However, the actual amount received was nearly $250,000 less than that, due to destruction of fishes in the net by marine mammals (Table 33). The cost of overhead to the fishery was increased by an additional $150,000 as a result of damages to nets by marine mammals. Altogether, this loss of potential and increase in overhead cost the fisherman some $360,000 (± about $60,000), or about $650 to $900 each in 1978.

The value of the marine mammals killed, incidental to the fishery, is more difficult to estimate. Assuming that the pelts of harbor seals are worth at least $20 each on the open market, and that those of sea otters are worth at least $100 each, a conservative estimate of the value of the pelts alone of these two species was between $6,000 and $17,000 (Table 34). Although the meat of marine mammals cannot be marketed in this country, it has considerable cash-replacement value to the native population that subsists on it. The meat of harbor seals is worth at least $2 per pound, while that of sea lions and porpoises may be considerably less, perhaps $.50 per pound. Thus, very conservatively estimated, the edible flesh (about 30% of total weight) of these mammals was worth at least $50,000 to $155,000. Other, intangible benefits could not be estimated, such as predation by these mammals on fishes that prey on or compete with the salmon. At any rate, crudely estimated, the monetary potential that was lost through incidental kill of marine mammals by the fisheries was at least $55,000 to $175,000 in 1978.

DISCUSSION AND CONCLUSIONS

The results obtained from the field and dockside sampling for the most part were remarkably similar, but in a few cases they were markedly

Table 33. Estimated potential dollar value of the fisheries, actual dollars received, and losses to the fisheries through damages to fishes and to nets by marine mammals, Copper River, Coghill and Copper-Bering River salmon gillnet fisheries, 1978.

Fishery	Potential value[a]	Actual value[b]	Losses		
			Fishes[c]	Nets[d]	Total
Copper River	$3,699,140	$3,595,361	$103,779	$142,238	$246,017
Coghill	$2,247,967	$2,231,682	$ 16,285	$ 4,316	$ 20,601
Copper-Bering	$3,155,983	$3,067,538	$ 88,445	$ 4,462	$ 92,907
Total	$9,103,090	$8,894,581	$208,509	$151,016	$359,525

[a] Approximate dollar value of all fishes caught, if none had been damaged.
[b] Approximate dollar value of deliveries, i.e. undamaged fishes, plus 50% value of salable damaged fishes.
[c] Approximate dollar value of unsalable damaged fishes, plus 50% value of salable damaged.
[d] Extrapolation to whole fishery, based on point estimates in Tables 11, 15, and 19.

Table 34. Approximate dollar value of marine mammals incidentally killed while interacting with the Copper River, Coghill, and Copper-Bering River salmon gillnet fisheries, 1978.

Commodity	Harbor seals	Sea lions	Sea otters	Harbor, Dall porpoises	Total
Pelts	$ 4,860-15,780	-	$900-1,100	-	$ 5,760- 16,880
Meat	$21,870-71,010	$27,270-85,050	-	$1,515-1,665	$50,655-157,725
Total	$26,730-86,790	$27,270-85,050	$900-1,100	$1,515-1,665	$56,415-174,605

different. These differences appear to have been mainly due to introduced biases and small size of the field samples. As indicated previously, stormy weather interfered with the field sampling during the spring Copper River fishery. One consequence of this was that sampling emphasis was greatest in protected areas, inside the barrier islands. This may have resulted in disproportionately higher estimates for damages by harbor seals and lower estimates for those by sea lions than would have emerged had that ideal random sampling scheme been completed. In dockside samples also, it was not feasible to obtain geographically random samples of the entire Copper River fishery, since fishermen returning to the docks (where they were interviewed) were mainly those that had fished in the West and Central subareas, nearest to Cordova. Those fishing in the East mostly stayed on the fishing grounds between open periods.

Similar problems were encountered in obtaining geographically random samples in the Coghill fishery. Because weekly sampling effort generally began in the North and terminated in the South subarea, "dockside" interviews tended to be clustered in the South. Although most of the fishermen also tended to move from North to South each week, this may have resulted in over-representation of those fishing only in the South and under-representation of those fishing only in the North. This may have been compensated for in part by the fact that the greatest proportion of the weekly deliveries was in the South. However, because most of the weekly deliveries in each subarea were made at the beginning of each week, the field sample comprised a greater proportion of the catch in the North than in the South.

In the autumn silver salmon fishery, the dockside surveys also over-represented the West subarea of the Copper River delta. An effort was made to balance this by interviewing fishermen returning to town from the more eastern areas by aircraft. However, the number of these was not sufficient to offset the larger number of samples from the West. After week 36 (10 September), it became impractical to continue the sampling, since nearly all of the fishing was centered on the East and Bering River subareas, from which very few fishermen returned to town between fishing periods.

In general, the dockside samples probably provided the better measure of overall interactions between marine mammals and the fisheries, and it is in the estimates derived from these that we place greatest confidence.

Patterns of Marine Mammal Depredations

The number of red salmon delivered to the cannery tenders in the spring 1978 Copper River gillnet fishery (approximately 222,000 fish) was the poorest since 1948. This was unexpected. Because of the poor run, it was necessary for the ADF&G to invoke emergency closure of the fishery in order to insure adequate "escapement" of fishes for spawning. Damages to fishes and nets by marine mammals also were less than predicted by the 1977 pilot study, perhaps because of the poor run of fishes and the low intensity of fishing effort. In the opinion of the fishermen, damages were considerably less than had been experienced in the previous two seasons.

As a result of closure of the Copper River fishery, fishing effort in the nearby Coghill district of Prince William Sound was greater than normal. There, the red salmon run was strong, and the catch was large. However, because of the unusually heavy fishing pressure, the ADF&G found it necessary to invoke emergency closure during the peak of the red salmon run (week 27), in order to insure adequate escapement. The greater than usual concentration of fishermen and nets in the Coghill district, together with the strong run of fishes, may have effected greater than usual marine mammal interactions with this fishery. However, the rate of occurrence of damages there seems never to be as severe as on the Copper and Bering River deltas.

The autumn silver salmon run in the Copper River-Bering River fishery also was very strong, and the catch was the best since 1968 for the Copper River and the best on record for the Bering River (Pirtle, 1976).

In the Copper River spring and Copper River-Bering River autumn fisheries, the dockside data indicated that, as the number of fishes caught per unit of time increased, the percentage of fishes damaged by harbor seals also increased. This suggests that those individuals who catch the largest number of fishes may suffer the greatest rate of damage by harbor seals (and may best afford the loss). A positive relationship between rate of harbor seal depredations and strength of the fishery also was suggested by the 1977 pilot study. Several thousand harbor seals apparently reside on the Copper and Bering River deltas during the spring, summer, and autumn (but not the winter), and many of them mate, molt, and feed there. While they apparently do not feed to any great extent on free-ranging salmon during most of this time (Pitcher, 1977 and unpublished), they do take advantage of fishes caught in nets. As the number of fishes caught per set increased, so did the rate of damages to those fishes, reflecting in part the opportunistic adaptation of the seals to an artificially and temporarily available resource (i.e. the netted fish).

The population of seals is not evenly distributed over the Copper River delta (and neither of course, are the fishermen). The site where the majority of seals were observed and the majority of damages occurred was the Central subarea, particularly near Grass Island bar. Our observations, as well as those reported by the fishermen, indicated that a large seal population was present also at the Kokenhenik entrance. Unfortunately, sampling bias in the dockside data, as well as in the field data, prevented estimation of damage rates in that area. Grass Island and Kokenhenik entrances accommodate the main channel of the Copper River, hence provide the best access for the seals to upriver haulout and pupping sites, as well as to the greatest concentration of upstream migrants of eulachon (*Thaleicthys pacificus*), which are their principal prey in spring (Imler and Sarber, 1947; Pitcher, 1977). Harbor seals were concentrated in those entrances even prior to the opening of the 1978 spring fishery, as indicated by observations from the R/V *Montague*.

During the autumn silver salmon season, the central area of the Copper River delta received very light fishing effort; fishermen tended to concentrate on the western end (Egg Island) and eastern end (Kokenhenik and Softuk) and increasingly on the Bering River delta as the season progressed. Although the 1978 field surveys indicated that damage was prevalent throughout the fishery, coincident with the extremely high catches, the fishermen reported a disproportionately large percentage of the damage in the Bering River district. Damages to this fishery by harbor seals tended to increase steadily during the survey period, as the catch also increased.

At Coghill, the pattern of harbor seal depredations overall did not show a strong positive correlation with the catch per week, but it was weakly correlated with catch in the North subarea. The rate of damage rose to its highest level in week 28 and was significantly lower in weeks 26 and 29. This pattern was consistent in both the field and the dockside data. The distribution and abundance of harbor seals appeared to remain constant during this period, although it is conceivable that some movement occurred. Females that pupped on the ice at the head of College Fjord may have moved southward into the fishery about week 28 (8-15 July), after their pups were weaned. The significant decline in damage rates from week 28 to 29 may have been related to the 22% decrease in catch in that period. During the entire fishery, harbor seals were noticeably more prevalent along the rocky shores than in the deeper waters, away from shore. Interactions between the fishermen and the seals also appeared to be more frequent in the nearshore zone. Those who often fished there remarked of "resident" seals, believing that they had repeated contacts with the same animals in specific areas. Conceivably, harbor seals in the Coghill district establish discrete home ranges along productive shorelines. Seals in pairs and small groups most frequently were observed in the vicinity of the Coghill River, and it was in that locality (North subarea) where the damages to caught fishes were greatest.

The pattern of depredations by Steller sea lions differed from that of harbor seals in each of the 1978 fisheries. On the Copper River, the percentage of fishes damaged by sea lions was not positively correlated with the weekly catch; it reached its highest level in the second week (week 21) which coincided with the peak of the salmon run but the lowest weekly catch of the fishery. In the 1977 pilot study, damages by sea lions tended to increase steadily over the first three weeks of the Copper River spring fishery, even though the catch per week and catch per fisherman had begun to decline.

A probable major factor affecting the pattern of sea lion depredations is their extreme mobility. They are not resident on the Copper River delta; the nearest rookery is at Cape St. Elias, some 60 km away. Apparently, they occur on the delta only in the course of wide ranging movements in search of food. Sea lions were present in association with the spring eulachon run, a week before the opening of the salmon fishery on the delta, but at no time were they abundant there. Their damages to nets and to caught fishes appear to be caused by a much smaller, more mobile number of animals than is the case with harbor seals. They appear to move into the Copper River area from offshore and distant rookeries and simply exploit the resource (netted fishes) as it becomes available. When there is a hiatus in the fishing (as occurred during the second period closure in week 21), the sea lions probably move on in search of other resources, possibly some distance away. During a spring fishing season with no such hiatus, such as in 1977, they probably tend to remain in the area and to increase in numbers during the season causing increasing amounts of damage until the catch markedly declines. As the fishery catch and effort severely decline, the number of sea lions probably also tends to decline locally. Steller sea lions were conspicuously absent during the fall silver salmon season on the Copper River-Bering River, presumably because they were utilizing some other resource, distant from the nearshore fishing grounds.

A few sea lions were observed and some damages by them were reported from vessels fishing the inside waters of the Copper River flats in spring, but the majority of interactions with them occurred outside the barrier islands. Whereas in 1977, the damages by sea lions to fishes and nets appeared to be greatest at first on the eastern end of the delta and to progress westward as the season advanced, the 1978 data indicated that damages were mainly centered in the outside waters of the Central subarea throughout the 3-week fishing season. Occasionally, fishermen were overheard on the radio discussing the movement of a particular sea lion as it progressed from one string of gear to the next. The observations by fishermen and biologists (J. W. Brooks, personal communication) indicate that extensive depredation by sea lions on the Copper River delta is a relatively recent phenomenon. The increase in sea lion-fishery interactions apparently has paralleled the increased fishing effort outside the barrier islands that has occurred since Imler and Sarber's (1947) observations.

The damages by sea lions were slight in the Coghill fishery, and the number of sea lions sighted was small. Data from both the field and the dockside samples suggest a higher rate of damages in the South subarea (south end of Esther Island) and a tendency for concentration near rocky islets (e.g. Egg Rocks and Esther Rocks). Damages were greatest in the final week of the fishery (week 29) when the catch showed significant decline. Since very few sea lions could be expected to occur in this extreme northwestern sector of Prince William Sound in the summer (K. Pitcher, personal communication), interactions with the fishery probably always are infrequent and more irregular than on the Copper River.

Both on the Copper River and at Coghill, there was a tendency for damages by marine mammals to occur more at night (0001-0600 hrs) than in the daytime and least often in the evening (1800-2400 hrs). Low light levels, accentuated by heavy clouds, made observation at night difficult for the fishermen, which may have contributed to the success of marine mammals in their depredations at that time. Long-term overnight sets, while the fishermen slept, were characteristic and provided abundant opportunities for extensive marine mammal interactions. Depredations by marine mammals occurred significantly more often in the afternoon (1201-1800 hrs) than in the morning or evening, possibly related to a circadian pattern of activity by the mammals themselves.

The probability of occurrence of depredations by marine mammals thus appears to be a function of numerous factors, including location time, catch rate, length of set, and perhaps the proximity of the fishermen to other vessels. Presumably, the distribution of depredation and damages over the fisheries is extremely uneven also because the fishermen themselves are not uniformly distributed or consistent in their fishing methods.

Incidental Kill of Marine Mammals

Rates of incidental capture and/or kill of marine mammals were estimated only from the dockside data. Use of field data for this purpose was precluded by the low frequency of interactions and the bias due to presence of the researchers.

The estimates of harbor seals and sea lions killed while interacting with the fishery were substantially higher in 1978 than were estimated from the 1977 pilot study. The 1978 estimates probably are much closer to the average kill figures, simply because of better data collection methods and larger sample size; hence, the apparent difference may not reflect any real change in the kill rates.

The 1978 data indicated that the kill of Steller sea lions (about 305 animals) was greater than of harbor seals (73 animals) during the spring Copper River fishery. This probably is more reflective of the difference in attitude of the fishermen toward each species than of their relative abundance or the frequency of their interactions with the fishery. Conversely, the majority of marine mammals killed while interacting with the Coghill fishery were harbor seals (about 118) rather than sea lions (about 20), which is more reflective of their relative abundance. Sea lions are scarce in the area utilized by this fishery. The kill of marine mammals in the autumn Copper River-Bering River fishery was limited to harbor seals (about 110); apparently, sea lions were absent from that area at that time.

It is extremely doubtful that the incidental kill of either seals or sea lions by these fisheries has any significant effect on their populations. Calkins *et al.* (1975) estimated the harbor seal population of Prince William Sound at more than 13,000 individuals and Pitcher (1977) estimated the harbor seal population on the Copper River delta at more than 3,000 animals seasonally. Over 37,900 sea lions were counted by Calkins and Pitcher (1977) on rookeries in the Gulf of Alaska, and pup production was estimated at over 17,900.

Of the marine mammals accidentally captured in the nets, some were extricated and released alive, but many died before removal was possible. Most often at night, they died before their presence was noticed. For some species, the estimates of total numbers taken by the fisheries are not well founded. For example, the estimate of 45 sea otters captured and released and 117 harbor seals captured and killed in the spring Copper River fishery were derived mainly from two reports. In one case, a fisherman netted 3 sea otters in a single set; in another, 7 harbor seals were accidentally captured and killed in an overnight set. Both fishermen agreed that these were very unusual occurrences, hence the extrapolation of these to the overall fishery may not be realistic (as the variances indicate). Estimates of the rates of capture and kill of harbor porpoises on the Copper River seem more reliable (58 captured and killed, 44 captured and released). Several veteran fishermen reported that, over their gillnetting careers (12 to 25 years each), they averaged one harbor porpoise caught per two years, and that porpoises were caught only in waters outside the barrier islands. Both the field and dockside data gathered in this study indicated that harbor porpoises were netted principally outside the islands, generally less than 5 km offshore. About 200 of the 450 fishermen on the Copper River delta regularly fish the outside waters. If the average "outside" fishermen nets porpoises at that same rate, then the catch per year may be about 100 harbor porpoises, somewhat more than half of which die before they can be extricated. The majority of porpoises seem to be captured on the western half of the delta, between Strawberry and Pete Dahl entrances.

Harbor porpoises were conspicuously absent from the deepwater Coghill fishery in 1978, but Dall porpoises were common there in southern Port Wells and off the south end of Esther Island. This scarcity of harbor porpoise is unusual (Islieb, personal communication). Our data indicate that about 41 Dall porpoises were captured, 10 of which were released while the rest died in the net. A few sea otters (estimated 10 released and 10 killed) and harbor seals (estimated 24 released and 28 killed) also were taken. Far more salmon sharks (estimated 54 released and 323 killed) than marine mammals were entangled in the nets, and most of those that were released probably died. The estimated number of Dall porpoises killed in 1978 was higher than predicted by the 1977 pilot study, perhaps because of the more intensive fishing effort in the Coghill district than in the past.

No harbor porpoises were reported netted during the autumn Copper River-Bering River gillnet fishery. However, harbor seals (estimated 33 captured and released, 11 captured and killed) and sea otters (estimated 11 captured and released) were taken. In this as well as the Copper River spring fishery, the sea otters were captured on the western end of the delta, to which they recently have expanded their range from Prince William Sound.

The effects of the incidental kill on harbor and Dall porpoise populations are unknown, inasmuch as there is no knowledge of the status of these populations. Both species seem to be abundant, hence it is doubtful that the incidental catch has any significant effects on their status. The number of sea otters killed also seems unlikely to have any major effects on the large, expanding population of the Prince William Sound region. Recently, Schneider (1978) estimated that population at 4,000 to 6,000.

Attitudes of the Fishermen

Fishermen tend to be very individualistic, and their attitudes toward the presence of marine mammals in or near the nets is extremely varied. This variation is due in part to the extent of their experience, their level of success in fishing, and to a large degree, the kinds and amounts of losses that they have endured from marine mammals. At one extreme is a minority that regards sea lions as worthless and seals as nearly worthless. These people would prefer to exterminate both of them or at least shoot them on sight. Some of these fishermen go out onto the fishing grounds prior to the opening of the fishing season, where they attempt to reduce the numbers of harbor seals and Steller sea lions by killing them with high-powered rifles. They feel that they are performing a "service" which should be done on a larger scale by professional hunters. One individual interviewed estimated that he had killed approximately 100 harbor seals and 15 sea lions on the Copper River flats, before the 1978 fishing season began. At the other extreme are fishermen who never carry a rifle or any other means for frightening or killing marine mammals. These people seem to view the occasional loss of fishes and gear as a hazard of the occupation. This group also is a minority and is made up mainly of those who have had few or no serious confrontations with marine mammals.

The majority of fishermen carry rifles or shotguns and/or seal bombs. The firearms are used mainly to frighten animals away from the gear or, secondarily, to kill them if the former is unsuccessful. Seal bombs are large (approximately 7.5 x 1.2 cm.), weighted firecrackers that are lighted and thrown into the water, where they generally explode several feet beneath the surface. The shock wave from the explosion can be felt through the hull of the boat and, presumably is strong enough to cause some pain or injury to the seal or sea lion at which it is directed. About 80% of the fishermen interviewed felt that these bombs are very effective in frightening seals and sea lions away from the nets, at least temporarily. In the course of the field sampling, the author observed the use of these devices by fishermen to drive harbor seals away from the net. In each case, the animals that had been in the area immediately disappeared and were not seen again. Problems and limitations associated with the use of seal bombs include (1) they are dangerous and can cause injury to the fishermen, (2) they also may frighten the fishes,

(3) they are expensive and not readily available (federal regulations prohibits interstate transport of such explosives from Washington to Alaska), (4) the marine mammals frequently return, and (5) there is the possibility that the shock wave may cause permanent physical damage to the marine mammals. Numerous others reported that they typically sustain less damage from seals and sea lions and no decline in the availability of fishes when killer whales are present in their area. Some fishermen expressed interest in the use of killer whale vocalizations as a possible method for discouraging marine mammal depredations.

Problems in Assessment of Damages

The possibility of fishes being removed entirely from the net, without leaving a trace, was a major concern in the case of depredations by sea lions. In dockside interviews, fishermen often remarked that their estimates of loss of fishes to sea lions were low because they could not account for those completely removed from the net. Depredations by sea lions on netted salmon tended to be far more extreme than those by harbor seals. Where such evidence did occur, the affected fishes mostly were represented by mere fragments (Figure 8, 9). In field sampling, the author observed that, when a sea lion swam through a net, little evidence remained of any fishes removed.

The Steller sea lion when "working the gear" tends to be aggressive and quick. It relies on speed and agility to obtain fishes from the net and effect its escape before the fisherman has time to respond. Occasionally, the reverse will be true; the sea lion will ignore the fisherman until its life is endangered or the fisherman picks up his net.

This kind of behavior infuriates the fishermen and is one reason for their generally hostile attitude toward sea lions. Conversely, harbor seals usually take a more stealthy approach, surfacing some distance away from the net, appearing relatively uninterested in the activities of the fisherman. Then in a long dive, the seals secretively approach the net and remove parts of the entangled fishes, then swim off some distance before surfacing again.

In nearly all cases where damages attributed to marine mammals were recorded, the mammals themselves were seen near the gear. However, they were seldom seen actually mutilating the netted fishes. To this extent, the recognition of "damage by marine mammals" was by inference, but this was tantamount to certainty, because there were few other fishes or mammals in the area capable of inflicting the damages observed. Although salmon sharks were abundant in the Coghill district, and many were caught in the gillnets, the damages inflicted by them in nearly all cases were limited to one or two fishes nearest them in the net. Apparently, these large sharks (up to 10 feet in length) do not have the maneuverability to remove parts from the fishes without becoming entangled in the nets. Only one fisherman reported that he observed several netted fishes that had been cut off cleanly at mid-section, unlike damages by marine mammals, and that a salmon shark had become entangled farther down the net. This series of bisected fishes was presumed to have been damaged by the shark. The only other abundant shark that might damage salmon is the dogfish (*Squalus acanthias*), but generally it is too small to cause the type of damage attributed to marine mammals. At Coghill, one report was received of a sea otter partially consuming three netted salmon while the fisherman watched it; however, this seems to have been an unusual situation.

The extent of damage to nets by marine mammals was more difficult to assess than damages to fishes. Unless the research team was present and noted the condition of the net when it was set out, they could not be certain that the holes in the retrieved net were made during the set observed, or that they had been made by marine mammals. They could attribute damage to marine mammals only when the damages were associated with damaged fishes. This probably resulted in great underestimation of the net damage in the field sampling especially on the Copper River, where the estimates were most conservative. In dockside surveys, fishermen frequently were interviewed while they were mending their nets, at which time they were acutely aware of all new holes that had developed during the previous week of fishing. Unfortunately, damages inflicted by marine mammals *versus* those caused by snags or backlashes (hangup and ripping of the net as it leaves the reel) were almost impossible to differentiate, and it is conceivable that they were not always identified accurately. Since rips and holes tend to enlarge with continued fishing, this also may have contributed to overestimation of damages. For these reasons, our estimates of net damage must be considered very approximate; hence, they have been treated only as point estimates. Of course, fishing time lost as a result of net damage and impaired efficiency of the net due to such damage are other sources of economic "loss" to the fishermen that are difficult to estimate and have not been taken into account in this report.

Generally, major damage to the net was concurrent with damage to fishes, particularly when sea lions were involved. Harbor seals occasionally made numerous small holes, apparently while removing fishes from the net. Sometimes they became wrapped in a net, causing more extensive damage. On the Copper River, occurrence of net damage rose to its highest rate coincident with the peak rate of damage by sea lions. In the Coghill fishery, net damages due to salmon sharks far exceeded all estimates of damage due to marine mammals. These were inflicted by an estimated 400 or more sharks that became entangled in the nets during the course of the fishery. The only major net damage there and in the Copper-Bering autumn fishery that could be attributed to harbor seals occurred concurrent with the peak rate of damage to fishes by those seals.

The cost to the fishermen of damages caused by marine mammals to potentially valuable fishes and nets was a small proportion (about 4%) of the total dockside value of the fisheries in 1978. However, it involves more than direct economic loss. Such intangibles as reduced efficiency of damaged gear, time lost in repair or replacement of gear, time spent in removing animals entangled in the gear, and loss of marine mammals that play an important role in control of predators and competitors of the salmon themselves also must be considered. In addition, important moral, political, and social conflicts are aggravated by these interactions. Most of the fishermen appreciate, even welcome the presence of marine mammals in this maritime wilderness in which they conduct their work, and it is with reluctance and some trepidation that they exercise control over these natural competitors. Most of them abhor the waste involved in the incidental kill of these mammals, particularly inasmuch as present federal regulations do not permit them (except Alaskan natives) to salvage any parts that might have tangible value to them. Their willingness to participate in this study has demonstrated that they are acutely aware of all aspects of the problem and are ready to assist the responsible state and federal agencies in seeking an equitable solution.

RECOMMENDATIONS

Reduction of Impacts

One of the specific objectives of this study was to utilize the information obtained by it for the purpose of devising means for reducing the impact of marine mammals on the fisheries as well as for reducing the impact of the fisheries on the mammals. Under present circumstances, mammal "control" measures, such as were practiced in the past, are not tenable. Solutions must be found that not only favor the fisheries, which are of vital economic importance, but also favor the marine mammals. The results of this study offer some partial solutions to the problem and suggest some possibilities that would bear further investigation.

The findings indicate that damage rates to fishes and nets, and the rates of incidental kill of marine mammals probably could be significantly lowered if the following circumstances were avoided:

1. Long-term sets, especially overnight when nets are unattended.
2. Fishing in early morning and afternoon.

3. Fishing in the main entrances and "outside" waters of the Copper River.

4. Fishing nearshore and in estuaries in the Coghill district.

Fishermen who fail to heed these recommendations must expect to sustain the highest rates of damages to fishes and nets.

Deterrent devices, such as "seal bombs", appear to be effective in driving away marine mammals that are actually or potentially interfering with fishing operations. Use of these should be encouraged, in place of firearms.

Future Research

Perhaps the foremost need for research at this time in the Copper River-Prince William Sound fisheries is the technological development and testing of devices useful in repelling marine mammals from the nets. The obvious first choices for testing are the seal bomb and the underwater calls of killer whales. Other possibilities may be electronically devised sonic devices (underwater "noise-makers") and dyes or other visual repellants (e.g. killer whale or human silhouettes). Field tests will need to be carefully designed experiments with adequate controls.

Also necessary is the development of techniques that will allow assessment of both the numbers of fishes totally removed from the nets and the amounts of net damage in which no evidence (i.e. parts of fishes) remain. Such losses may be large, but at present, there is no basis for their estimation; indeed, they are only assumed, not known to occur. Possible experimental approachs might involve the use of marked fishes and use of nets in known condition in areas of greatest harbor seal and Steller sea lion activity.

Conceivably, some intensive studies of the behavior of marine mammals in and near the nets would provide additional clues to potential non-destructive control measures. These studies would involve field observation in the areas and at the times identified by the present study as being most contributive to major damages by marine mammals. They could be conducted concurrently with the experimental manipulations previously suggested. The spring Copper River fishery should be the focus of this research.

Mammals incidentally killed, whether from accidental entanglement or intentional shooting, should be examined in detail, especially for information on age, sex, stomach contents, and physical (including pathological) condition. This is a substantial quantity of material that is presently being wasted, and that might provide some further clues useful in devising non-destructive control methods.

Given that the foregoing recommendations for reduction of impact on the fishery are followed, and that further benefits are derived and applied from the studies mentioned above, a follow-up study eventually should be conducted to assess the change in damage rates. The procedures would be basically the same as in the present study, with the following exception:

Field sampling should be carried out by at least two, preferably three research teams on the Copper River delta, at least two on the Coghill, and at least three on the Copper-Bering deltas. These should provide field samples of more reliable size and representation that could be used for estimation with greater confidence on a fishery-wide basis.

In the event that this modification is not economically feasible, greater emphasis should be placed on enlargement, refinement, and better representation of the dockside samples. Some field sampling, even if at a low level, should be conducted as well, since this provides exceptional insights into the fishing procedures and the activities of the marine mammals, both of which are needed for rational evaluation of the results.

General Remarks

There is a need to review and rectify present problems in the Certificate of Inclusion permit system. Under federal regulation, these permits, issued to the individual fisherman for a fee of $10 annually, allow legal incidental taking of marine mammals and require the permittee to provide data as to the kinds and numbers of mammals taken, and when, where, and how they were taken. Alaskan fishermen in general and those of the Copper River-Prince William Sound region, in particular, passively object to this as an imposition, on the grounds that (a) they have no control over the actions of the marine mammals and, therefore, should not be "punished" (by fee and reporting requirements) for something that is tantamount to an "act of God"; (b) the mammals themselves are already causing them to suffer substantial economic loss, therefore they should not be obliged to pay for the questionable right to suffer that loss. Consequently, very few of them have applied for and possess Certificate of Inclusion permits for their salmon gillnet fishing. While it is presumed that the Certificate of Inclusion provision was intended primarily as means for the federal administration to acquire at their convenience some firm data on rates and kinds of incidental kill, it appears to have had a substantially adverse effect in turning the fishing community against the administration, and to have had little or no beneficial effect in providing the desired information. The Certificate of Inclusion regulation, therefore, seems to have been ill-conceived, to be largely ineffective, and in need of either deletion or thoughtful revision. A series of public hearings on this measure, in the fishing communities, would seem to be highly desirable at this time.

From discussions with the fishermen, it is concluded that much of the resentment and mental anguish that is generated by interactions with marine mammals would be relieved if the mammals themselves were available for gainful harvest. Currently, harvesting of marine mammals is limited only to Alaskan natives (Eskimos, Indians, and Aleuts), who may kill them for "subsistence" purposes. This has created a serious rift in an otherwise closely knit community of natives and non-natives. Prior to the Marine Mammal Act of 1972, controlled harvest by any Alaskans, native or non-native, was allowed under ADF&G administration, and the animals killed incidental to the fishery were a part of that harvest. Ability to possess and sell the pelts and meat of these animals permitted many of the fishermen to recoup the financial losses that they had sustained from damages to fishes and gear, i.e. the mammals, as well as the fishes, were a valued resource, rather than simply a competitive nuisance. It seems that reestablishment of such a controlled harvest scheme would have a distinctly beneficial effect on both economics and attitudes in the fishing community.

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APPENDIX I

GENERAL DISTRIBUTION AND INTERACTION OF MARINE MAMMALS WITH THE COPPER RIVER-PRINCE WILLIAM SOUND FISHERIES

Humpback whale (*Megaptera novaeangliae*)

Humpback whales are most abundant on the western side of the Sound, particularly in the southwestern corner; they are rarely seen in the vicinity of the Coghill drift gillnet fishery or of the Copper River fishery. The number of animals present in Prince William Sound during the summer has been estimated at 60+ animals (Hall and Tillman, 1977). Interactions with fisheries generally have been limited to the salmon purse seine fishery. Several verified accounts of humpbacks puncturing salmon purse seines with considerable damage to the nets have been reported in the Chenega Island-Chenega Point area. Humpback whales are known to take salmon only incidentally (Fiscus, 1978), although they may feed on herring (another locally commercially important fish) and other small or juvenile fishes.

Minke whale (*Balaenoptera acutorostrata*)

Probably the most abundant and ubiquitous baleen whale in the Sound is the minke whale. Concentrations seem to occur in the western parts of the Sound, particularly in the Green Island-Montague Strait area and in the Storey-Naked-Peak Island area. Apparently, these whales are uncommon on the Copper River delta, but they were occasionally sighted in the Coghill district and were reported (rarely) to swim through gillnets, causing considerable damage to the nets. Otherwise, direct interaction with the fishery has been slight. Minke whales are not known to prey on salmonids (Fiscus, 1978); small fishes (including herring) make up the bulk of their diet.

Finback whale (*Balaenoptera physalus*)

Fin whales are seen in the area mainly in spring and early summer (May-June), often near ocean entrances and in the central Sound. Occasional sightings have been reported from many localities, but these whales are uncommon on the Copper River delta. Salmonids have been reported as incidental food items, although their occurrence is very unusual (Fiscus, 1978). Little or no interaction is likely to occur with local fisheries.

Killer whale (*Orcinus orca*)

Seasonally abundant in the Sound, the killer whale population probably is highest during the pink salmon return (late July and August). Killer whales occasionally are observed on the Copper River delta in spring and summer. Population centers seem to be in the western Sound, particularly the southwestern corner, where up to 55 individuals have been sighted in a single group (C. Matkin, personal observation). The peak seasonal population probably exceeds 100 animals in Prince William Sound. Gillnet fishermen state that the killer whales generally are adept at avoiding nets, and many claim that sea lion depredations are reduced where killer whales have been sighted recently. Although killer whales often are present adjacent to seining operations, they infrequently penetrate nets. There is one documented case of a killer whale drowning in a seine lead (left in the water overnight) during the 1978 season. It is conceivable that killer whales compete directly for salmon through predation on free-swimming stocks, since they are known to prey on salmon (Fiscus, 1978).

Harbor porpoise (*Phocoena phocoena*)

The secretive harbor porpoise is common in parts of Prince William Sound and the adjacent Copper River delta apparently year round. They seem particularly abundant outside the barrier islands on the delta, especially in the western half. They are infrequently encountered in the Coghill fishery, as indicated by the lack of any reported interactions and sightings by the investigators in 1978. On the Copper River delta, as many as 100 may be captured in gillnets in the spring season, about one-half of which are released unharmed. Interaction with the salmon purse seine fishery is infrequent, although an occasional animal may swim into a net and be released unharmed. Although it is likely that Pacific salmonids are too large for this species to consume, small salmonids in the North Atlantic have been reported as prey (Fiscus, 1978).

Dall porpoise (*Phocoenoides dalli*)

Apparently the most numerous cetaceans in Prince William Sound, Dall porpoises are year round residents; they appear to increase in numbers in the summer months (Hall and Tillman, 1977). Most abundant in the western Sound and the ocean entrances, they also are found offshore on the Copper River delta, generally two miles or more outside the barrier islands. They are infrequently netted on the delta but occasionally run through or are captured in gillnets at Coghill. An estimate of 41 Dall porpoises (possibly high) captured in gillnets was made for Coghill in 1978, ten of which were released unharmed. These porpoises are not known to compete directly with the salmon purse seine or gillnet fisheries. Although small fishes and squids are their primary prey, one red salmon was reported in a stomach (Fiscus, 1978). One Dall porpoise was observed at the surface with a salmonid (apparently a pink salmon) in its mouth in Prince William Sound (C. Matkin, personal observation).

Sea otter (*Enhydra lutris*)

Sea otters have expanded their range considerably in the Sound in recent decades and now occur on the western delta of the Copper River. Otters are found also in the Kayak Island-Bering River area (Schneider, 1978). They have extended their range into the Coghill area where they are sometimes caught in gillnets. Of an estimated 20 otters captured there, half were released unharmed in 1978. They also are netted occasionally on the western end of the Copper River delta. In areas of high otter concentration, they may be captured in seine leads (especially if left out overnight) and have been known to destroy the foam floats on seine leads. Occasionally, otters are captured in purse seines and released unharmed. One sea otter was reported removing and consuming gillnetted fishes in the Coghill area, although this also certainly is unusual. Sea otters are known predators on bivalves, and a potentially serious conflict exists if commercial clamming in the Sound is expanded as anticipated. Sea otters also have been observed feeding on commercially valuable Dungeness crab (C. Matkin, personal observation).

Steller sea lion (*Eumetopias jubatus*)

Steller sea lions are year-round residents of the Sound but are relatively scarce in the Coghill area during the gillnet season. There is an apparent movement of sea lions into the Sound in winter (Calkins and Pitcher, 1977). Although present on the Copper River delta in the spring and summer, they evidently are absent by the time the autumn silver salmon season begins (mid-August). Their interactions with the salmon gillnet fishery are discussed in the text of this report. Occasionally, they also are captured in salmon purse seines. Feeding habits are discussed in Appendix II.

Harbor seal (*Phoca vitulina*)

The harbor seal is abundant in Prince William Sound and on the Copper River delta. On the delta their presence is seasonal; they are absent in the winter. The river bars are used by them as pupping and molting sites in spring and summer (Pitcher, 1976). They apparently pup (and frequently haul out) on ice in areas with tidewater glaciers in the Sound, such as College Fjord and Harriman Fjord in the Coghill district, and in Unakwik Inlet, where approximately 1,500 were sighted (C. Matkin, personal observation). Interactions with the salmon gillnet fishery are described in the text of this paper, and the food habits are discussed in Appendix II. They are occasionally captured in salmon purse seines.

Other marine mammals

Other mammals may be sighted infrequently or may pass through the area on a regular basis but are not known at this time to have any important direct or indirect interaction with the fisheries. These include the gray whale (*Eschrichtius robustus*), belukha whale (*Delphinapterus leucas*), northern fur seal (*Callorhinus ursinus*), sei whale (*Balaenoptera borealis*), Pacific white-sided dolphin (*Lagenorhynchus obliquidens*), and beaked whales (*Mesoplodon stejnegeri* and *Ziphius cavirostris*).

APPENDIX II

FOOD HABITS OF THE STELLER SEA LION AND HARBOR SEAL IN THE GULF OF ALASKA

In the Gulf of Alaska and in Prince William Sound, harbor seals (*Phoca vitulina*) and Steller sea lions (*Eumetopias jubatus*) have not yet been indicated as major predators on commercially important fishes. Much of the collection and examination of animals, however, has been in areas where or at times when salmon, the commercial species discussed in this paper, probably have not been abundant or present.

Steller sea lions were collected by Imler and Sarber (1947) from the Gulf of Alaska and southeastern Alaska. Of eight sea lions collected in southeastern Alaska in May and August, all but one had fed principally on pollock (*Theragra chalcogramma*). Of seven animals collected in July in the Gulf of Alaska on the Barren Islands, Chiswell Islands, and Kodiak Island, two from the Chiswell Islands contained entirely salmon (*Oncorhynchus* sp.), and one contained 10% halibut (*Hippoglossus atheresthes*). One of the former contained a whole, eight pound red salmon. Other food items included starry flounder (*Platicthys stellatus*), arrowtooth flounder (*Atheresthes stomias*), pollock tomcod (*Microgadus proximus*), and octopus (*Octopus* sp.). Thorsteinson and Lensink (1962) reported rockfishes (*Sebastes* sp.), greelings (Hexagrammidae) and cephalopods as food items from nine animals collected at Marmot Island. Mathisen *et al.*, (1962) reported that 27% of the stomachs from 114 adults collected in June and July on the Shumagin Islands contained fishes; the rest were empty. Remains of pink salmon (*Oncorhynchus gorbuscha*) were found in one stomach while smelts (Osmeridae), greelings, rockfishes, and sculpins (Cottidae) were the major food fishes found in all. Squid (Decopoda) and octopus (Octopoda) were the most common invertebrate prey. Ficus and Baines (1966) reported on stomach contents of five sea lions taken in the Gulf of Alaska during May and June, in conjunction with pelagic fur seal studies. One stomach contained 95% (by volume) salmon, while others contained principally sand lance (*Ammodytes hexapterus*) and capelin (*Mallotus villosus*), with some rockfish, sculpins (Cottidae) and Cycopteridae. Calkins and Pitcher (1977) found pollock to be the dominant food in 83 stomachs and intestines examined mainly in October to April. Other species regularly utilized included Pacific cod (*Gadus macrocephalus*), Pacific sandfish (*Trichodon trichodon*), capelin and several kinds of Pleuronectidae. None contained salmon; however, it should be noted that nearly all the animals were collected in winter in areas where salmon probably were not present.

Harbor seal feeding habits in the Gulf of Alaska have not been well documented in the past but are currently under intensive study (Pitcher and Calkins, 1977). Imler and Saber (1947) collected 99 harbor seals in southeastern Alaska and 67 on the Copper River delta in 1945 and 1946. Those from southeastern Alaska indicated that pollock and herring were the principal prey items, with pleuronectids and eulachon also important. In 1945 salmon occurred in 13% of the stomachs, but in 1946 they were found only in 2%. Interestingly, this correlates with a good salmon return in 1945 and a poor return in 1946. This underlines the relationship of rate of predation (as well as the depredations discussed in the text) with the abundance of possible prey items (i.e. free swimming or netted salmon).

Imler and Sarber's harbor seals were taken from the Copper River in late May and June, during the eulachon (*Thaleicthys pacificus*) run, and 64 of the stomachs contained only eulachon. Of the three remaining stomachs, one contained cod and the other contained salmon. Most of the seals were taken from protected areas, behind the barrier islands or upriver. However, the two containing salmon were taken well out on the flats. Pitcher (1977) sampled 45 harbor seals on the Copper River delta in June, July, and September. In these also, eulachon was the dominant food, occurring in 78.6% of the 28 seals containing food and in all but one of the July samples. One seal taken in July contained a red salmon (*Oncorhynchus nerka*). In the seals taken in September, prey included herring (*Clupea harengus*), pollock and sculpin (*Leptocottus armatus*), evidently taken from estuarine areas. The distribution of sampling effort (i.e. upriver, outside barrier bars, etc.) was not indicated.

Pitcher's (1977) analysis of 151 stomachs of harbor seals taken in Prince William Sound was similar in some respects to the findings of Imler and Sarber (1947) in southeastern Alaska. Gadids (especially pollock) and herring were the principal prey; a lesser dependence on pleuronectids and greater dependence on cephalopods also was found. Salmon constituted an important proportion of the prey (14% of the occurrences) only during July and August, when these fishes became abundant in the Sound.

Further work by Pitcher and Calkins (1977) in examining stomachs and large intestines of harbor seals collected in the Gulf of Alaska, indicated gadids (33.6% by frequency of occurrence), cephalopods, mainly *Octopus* sp. (14.2%), Pleuronectidae (9.3%), Ammodytidae (7.5%), Osmeridae (7.1%) and Cottidae (6.2%) as principal prey groups. The species best represented included pollock, *Octopus* sp., pacific cod, sand lance, and capelin.

The data on Steller sea lion and harbor seal food habits indicate a wide range of prey species and the importance of location and timing of collections in determining the normal year round diet. Pinnipeds taken several miles apart may contain considerably different prey, as indicated by Imler and Sarber (1947) for the Copper River delta. Timing also is important especially for assessing the level of predation on anadromous fishes. The strength and timing of fish runs may have a strong influence on predation, especially in the case of salmon which are locally abundant only at specific times.

There are numerous geographic and temporal gaps in the picture of Steller sea lion and harbor seal food habits in the Gulf of Alaska. It is evident salmon are not the principal prey during most of the year, but that they may be important as prey in specific areas and time periods. This needs to be assessed further in places and times of high salmon concentration. One of these is the area outside the barrier islands on the Copper River delta in early summer, when both seals and sea lions congregate, possibly in response to the salmon return and the activity of the fishery.

APPENDIX III

SUBSISTANCE TAKE OF HARBOR SEALS AND STELLER SEA LIONS IN PRINCE WILLIAM SOUND

The following are the total number of pelts received from the only local, authorized, purchasing/processing agent for marine mammal pelts in the Prince William Sound native subsistence area*:

1976	1977	1978
392 harbor seals	275 harbor seals	445 harbor seals
1 sea lion	6 sea lions	3 sea lions

Although the number of pelts received does not necessarily indicate the total take of marine mammals by natives, these figures are conservatively suggestive of the current level of subsistence harvest.

*Courtesy of Larry Kritchen, Cordova, Alaska.

APPENDIX IV

DOCKSIDE SURVEY FORM FOR 1977 PILOT STUDY

Survey form - Copper River delta   Seal and sea lion damages

Week (dates) ____________ Location ______________________________

Estimated total number of fishes caught __________ (include damaged fishes)

Estimated number of fishes damaged by seals _______ sea lions ________

Estimated gear damage (dollar amount) __________ by __________________

Estimated number of seals in the area _______ sea lions ______________

other marine mammals_____________

Please fill this out for each week's fishing whether or not there was any marine mammal damage.

APPENDIX V

MARINE MAMMAL FISHERY INTERACTION

FIELD DATA FORM (1978)

District: 212-10 223-20 200- I.D. # ______
212-20 223-30
212-30 223-40

Location: Copper River - inside / outside Coghill / Bering R. ______

Date: ______ Wk.# ______ Period ______ Time: Start ______ Fin. ______

Tide: HE LE / HF LF Other Conditions : Sea state - Calm Slight Chop Rough
Visibility - Good Fair Poor

sets ____ Drift times (min.) ____ ____ ____
Haul times (min.) ____ ____ ____

Total Catch (includes damaged fishes)				
	red salmon	____	____	____
	king salmon	____	____	____
	pink salmon	____	____	____
	dog salmon	____	____	____
	silver salmon	____	____	____
# marine mammals working gear	sea lion	____	____	____
	seal	____	____	____
	UNK	____	____	____
	______	____	____	____
# fishes damaged salable/unsalable	sea lion	____	____	____
	seal	____	____	____
	UNK	____	____	____
	______	____	____	____

Total gear damage: (sq. feet net) sea lion ____ seal ____ UNK ____ ____ ____

Total incidental kill: sea lion ____ seal ____ ____ ____

Total direct kill: sea lion ____ seal ____ ____ ____

Total live release: sea lion ____ seal ____ ____ ____

Remarks: (including # boats in area, etc.)

APPENDIX VI

MARINE MAMMAL-FISHERY INTERACTION

DOCKSIDE SURVEY FORM (1978)

District: 212- 200- 223- I.D.# ______

Date: ________ Wk# _______

Areas fished: ____

What was your approximate total number of fishes caught of each species (include damaged fishes)? ______________________________

How many of those fishes were damaged by a marine mammal and could not be sold? _______ by seals _______ by sea lion _____ by UNK

How many fishes were damaged and could be sold? ________ seals ________ sea lions ________ UNK

How much gear damage was done by marine mammals? (in sq. ft. net) _____ by sea lions _____ by seals _____ by _____

In what area were most of the marine mammal damages inflicted?

____

Were any seals, sea lions, porpoises, sea otters or other marine mammals captured and/or killed accidently or intentionally during fishing activities?

Captured/kill : seals _____ sea lions _____ Other _____
Live release : seals _____ sea lions _____ Other _____
Direct Kill : seals _____ sea lions _____ Other _____

Remarks: