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Killer Whale *(Orcinus orca)* Depredation on Longline Catches of Sablefish *(Anoplopoma fimbria)* in Alaskan Waters

July 1988

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KILLER WHALE (*Orcinus orca*) DEPREDATION ON LONGLINE CATCHES OF SABLEFISH (*Anoplopoma fimbria*) IN ALASKAN WATERS

by

Marilyn Elayne Dahlheim

National Marine Mammal Laboratory
Northwest and Alaska Fisheries Center
National Marine Fisheries Service
7600 Sand Point Way NE, Bin C15700
Seattle, Washington 98115-0070

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ABSTRACT

Depredation by killer whales (Orcinus orca) on longline catches of sablefish (Anoplopoma fimbria), commonly called blackcod, has been documented in the southeastern Bering Sea and Prince William Sound areas. Results of dockside interviews conducted in February and March 1988 with domestic Bering Sea longline fishermen suggest that predation occurs on 20% of the sets with an average monetary loss of $2,300 per day incurred during the winter season. Japanese longline vessels fishing the Bering Sea between 1977 and 1985 reported whales interferring with operations on approximately 15% of their trips. In Prince William Sound, a 25% predation rate was reported based on interviews conducted with longline fishermen which suggests similar financial losses as those reported for the Bering Sea. Although interactions with killer whales and Alaskan longline operations have been documented as far back as the mid-1960's, it is not possible to determine if an increasing trend in killer whale depredation is occurring since reporting has been inconsistent. Various methods have been tried to reduce or eliminate whale depredation on commercially valuable fish. Limited success has been achieved by 1) the use of dummy buoys, 2) long-distance movements greater than 60 nautical miles, 3) temporary cessation of fishing activities, 4) changing the target species from blackcod to Pacific cod, and 5) the use of pot gear. The National Marine Mammal Laboratory will continue to collect information regarding killer whale fishery interactions in Alaska focussing on the impact on the fishery, calculating the number of killer whale pods involved, and developing possible ways to reduce or eliminate whale depredation on longline caught blackcod.

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INTRODUCTION

In August 1985, the National Marine Mammal Laboratory (NMML) learned of a fishery interaction involving killer whale (Orcinus orca) depredation on longline catches of sablefish (Anoplopoma fimbria), commonly called blackcod, in Alaskan waters. Fishery interactions were reported from the southeastern Bering Sea and Prince William Sound areas.

To assess the nature and magnitude of the interactions in Prince William Sound, the National Marine Fisheries Service (NMFS) Alaska Regional Office contracted studies focussing on dockside interviews with blackcod fishermen. These interviews were conducted after the seasonal closure of the 1985 fishery in Prince William Sound. Matkin (1986) reported blackcod longline losses of up to 25% of total catch, presumably due to killer whale depredation. A resident pod of killer whales (AB pod) was tentatively identified as being the only pod involved, and several members of this pod had holes or scars, which appeared to be bullet wounds, in the dorsal fins and elsewhere. The observation of these wounds raised concerns about increased mortality of killer whales from fishery interactions.

Fishery interactions with killer whales were again reported during the 1986 blackcod season in Prince William Sound. In June 1986, NMML contracted further studies in Prince William Sound (Matkin et al. 1987a) to assess and evaluate the extent and types of interactions that were occurring, and to develop recommendations to reduce them. Research objectives included: 1) onboard sampling to determine damage to fish or gear and the amount of losses in the catch directly attributed to killer whale predation; 2) photographs to identify individual killer whales and pods involved in the interactions; and 3) an assessment of killer whale mortality.

Concomitantly, NMML began a review of pertinent information relative to the killer whale/blackcod interactions in the Bering Sea which included:

1. A review of U.S. cruise reports from 1977 to 1985 completed by NMFS observers aboard Japanese commercial longline vessels in Alaska;
2. A review of Japan-U.S. cooperative longline research survey reports from 1978 to 1987;
3. Interviews with fishermen, Japanese scientists, Alaska Department of Fish and Game biologists, and marine mammal biologists; and
4. A review of the history and techniques of the Alaskan longline fishery.

Research by NMML continued into 1987 focussing on issues in the Bering Sea which consisted primarily of gathering additional information on the magnitude of the interactions and associated impact on the fishery. In conjunction with the fishing industry, survey forms and educational information were distributed among the fishermen in the blackcod fleet. In February 1988, NMML initiated pilot field investigations in the southeastern Bering Sea.

The purpose of this report is to summarize and integrate the available information on the killer whale/blackcod longline interactions in Alaskan waters. A brief introduction on the life history of killer whales and blackcod as well as a short description of the blackcod fishery is provided. A preliminary assessment of the impact of whales on the longline fishery is made and possible mitigating measures are discussed.

NATURAL HISTORY OF KILLER WHALES

Orcinus orca is a cosmopolitan species, inhabiting all major oceans and seas of the world (Leatherwood and Dahlheim 1978). Killer whales primarily occur within 800 km of coastlines (Mitchell 1975), and in Alaska major concentrations occur near land masses and over continental shelf waters (Braham and Dahlheim 1982; Fig. 1).

Killer whales typically occur in pods of fewer than 40 animals (Dahlheim 1981). Pod composition appears to remain constant through time with little intermixing of individuals among pods (Bigg 1982). Orcinus is a top-level carnivore of the marine ecosystem with diets that vary regionally. Although killer whales primarily eat fish, they also consume other cetaceans, pinnipeds, and sea birds (Dahlheim 1981; Table 1). Feeding activities appear to be group coordinated with different strategies employed depending upon the target prey. Blackcod has not been previously described as a prey item; however, this may be a reflection of our limited knowledge of feeding habits of North Pacific killer whales since only a small number of killer whale stomachs have been examined. In some areas killer whales appear to be resident (occupying areas on a regular basis) while in other areas they appear to be transient or migratory (occurring in areas on a seasonal basis only) (Bigg 1982). In most geographical areas, movements of killer whales seem to be related to movements in their food supply (Dahlheim 1981). With the exception of the inland waters of Washington State and British Columbia (Bigg 1982), and Prince William Sound, Alaska (Leatherwood et al. 1984), reliable population estimates are not available.

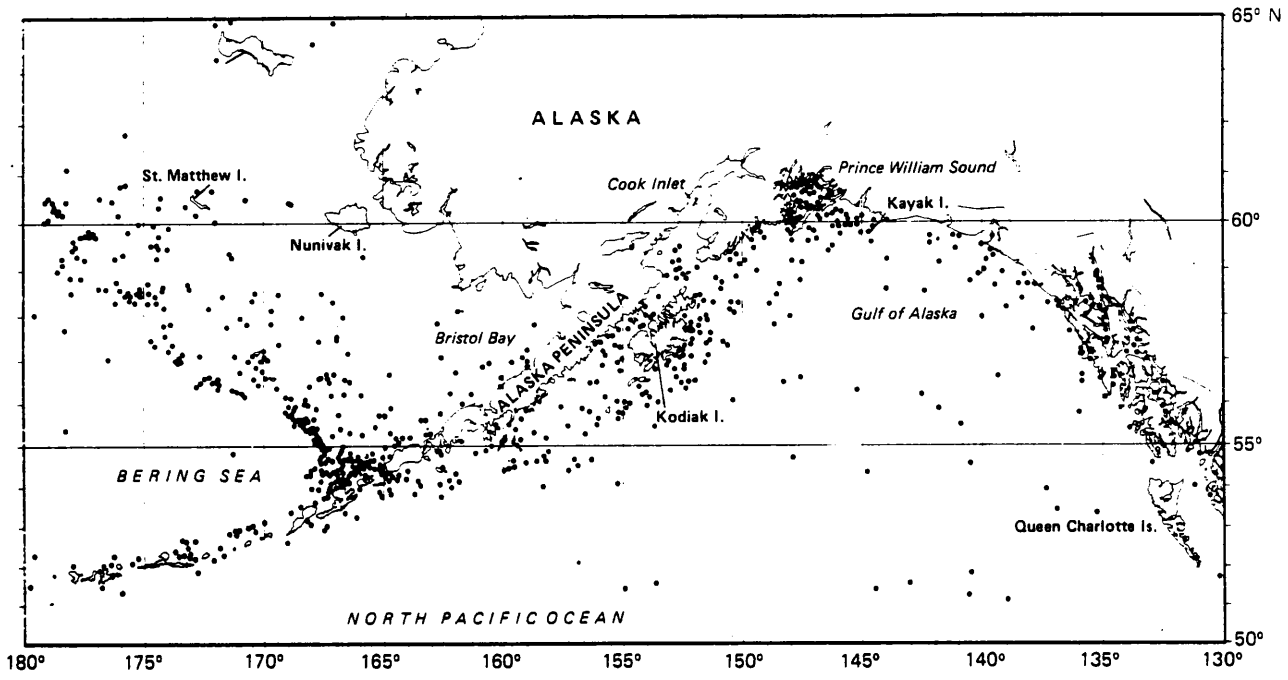

Figure 1.--Cumulative Sightings of Killer Whales in Alaskan Waters from NOAA's Platforms of Opportunity Program (NMFS), 1958-86.

Table 1.—Food of Northern Pacific Ocean killer whales (International Whaling Commission 1982).

Arctic and Sub-Arctic

Walrus (Odobenus rosmarus), bearded seal (Erignathus barbatus), ringed seal (Phoca hispida), salmon (Oncorhynchus spp.), northern sea lion (Eumetopias jubatus), Alaskan fur seal (Callorhinus ursinus), gray whale (Eschrichtius robustus, bowhead whale (Balaena mysticetus), white whale (Delphinapterus leucas).

References: Scammon (1874); Cook (1926); Zenkovich (1938); Nikulin (1941); Nishiwaki and Handa (1958); Fay et al. (1979); Braham and Dahlheim (1982).

Northeast

California sea lion (Zalophus californianus), elephant seal (Mirounga angustirostris), Dall's porpoise (Phocoenoides dalli), harbor porpoise (Phocoena phocoena), striped dolphin (Stenella coeruleoalba), minke whale (Balaenoptera acutorostrata), blue whale (Balaenoptera musculus), common dolphin (Delphinus delphis), harbor seal (Phoca vitulina), salmon, Pacific halibut (Hippoglossus hippoglossoides), carcharhinid shark, ray (Torpedo californica), greenling (Hexagrammidae spp.), ling cod (Ophiodon elongatus), squid, Pacific moonfish and deer (Odocoileus sp.).

References: Scheffer and Slipp (1948); Brown and Norris (1956); Nishiwaki and Handa (1958); Norris and Prescott (1961); Rice (1968); Barr and Barr (1972); Tarpy (1979); Balcomb et al. (1980).

Northwest

Cod (Gadus sp.), flatfish, sardine, salmon, tuna, mackerel, Atka mackeral, bonito, cephalopods (squid and octopus), Dall's porpoise, striped dolphin, Baird's beaked whale (Berardius bairdii), goose-beaked whale (Ziphius cavirostris), sei whale (Balaenoptera borealis), pilot whale (Globicephala macrorhynchus), finless porpoise (Neophocaena phocaenoides), harbor seal.

References: Nishiwaki and Handa (1958).

BLACKCOD FISHERY IN ALASKA

Blackcod are widely distributed in the North Pacific Ocean and Bering Sea (Fig. 2) and are a commercially important groundfish resource for these regions (Sasaki 1985). Adult fish occupy continental slope waters and have also been found on seamounts in the northeastern Pacific Ocean. The lower limit of bathymetric distribution is 2,740 m (Beamish et al. 1979). Juvenile fish are commonly found in surface waters and near the bottom in shallow nearshore waters of the northeastern Pacific Ocean, ranging from the Gulf of Alaska to California (Sasaki 1985). In the eastern Bering Sea, 1- and 2-year-old fish are rare; however, an extensive distribution of 1- and 2-year-old age classes was observed from Unimak Pass north to lat. 59°N. Concentrations of these young fish were centered in the 100 to 200 m depth zone and shallow water areas less than 100 m deep along the Alaskan Peninsula (Wakabayashi and Fujita 1981; Wakabayashi and Yabe 1981). Since fish size increases with depth, it is assumed that juvenile fish move into deeper waters and then recruit to the adult stock. Differences in maximum size of fish and variations in color are reported for different geographical areas.

The Japanese blackcod fishery was initiated in the northern Bering Sea in 1958 and then steadily expanded to other Bering Sea areas and the northeast Pacific. U.S. observers were placed aboard Japanese commercial longline vessels beginning in 1977, pursuant to the Magnuson Fisheries Conservation and Management Act, to document the number of fish taken and the species composition of the catch. U.S. interest in Alaskan blackcod increased during the late 1970's and early 1980's and by 1984 the blackcod fishery consisted primarily of U.S. domestic vessels.

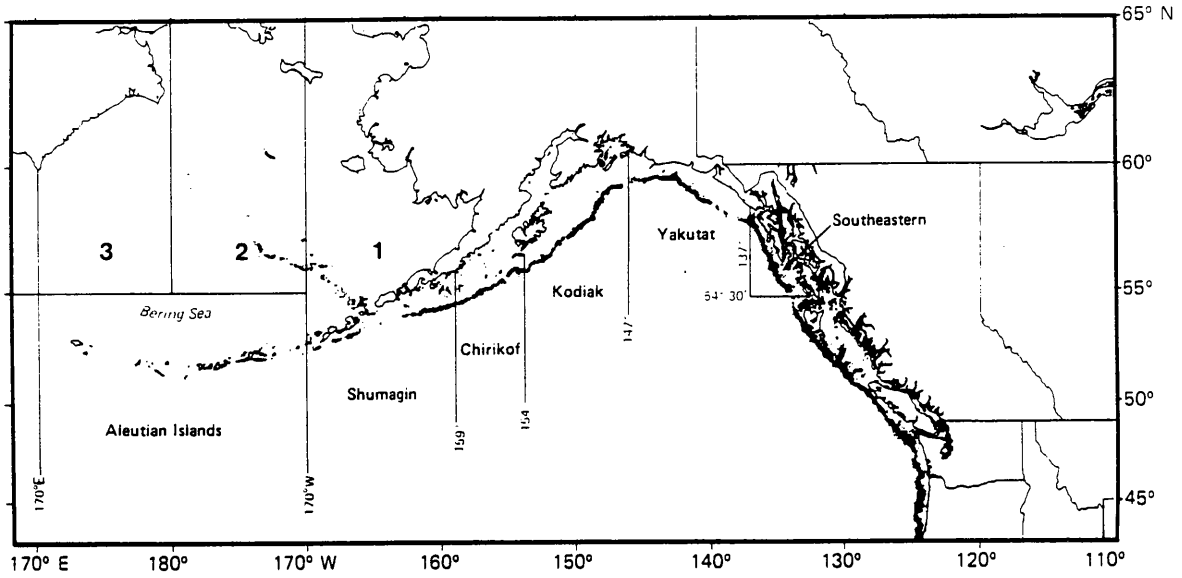

Figure 2.--Location of Blackcod Fisheries in Alaskan Waters. Courtesy of: Fujioka et al. 1988.

The blackcod fishery in Alaskan waters is still expanding. Three types of vessels comprise the directed fishery for blackcod: catcher boats, catcher/processors, and floating processors. Due to limited space, the catcher boats typically have shorter trip durations and smaller ranges in which to operate. Longline gear is used for most blackcod fishing, accounting for 80% of the blackcod caught in 1987, while trawl gear accounts for 16%, and traps (pots, rectangular and conical in design) account for 4%. Disagreements abound among fishermen using longline and pot gear as to which method is more effective (e.g., quality of fish, species selectivity of gear, efficiency of fishing, costs, etc.). A phase-out of pot gear has recently been taking place in the U.S. waters (Fig. 3). This phase-out plan does not include Prince William Sound (a State fisheries) or the Bering Sea.

During longline fishing operations, a weighted groundline approximately 3 nautical miles (nmi) in length is deployed from the fishing vessel. An average of 17 skates (usually 100-150 fathoms in length) makes up this groundline. Depths of 200-550 fathoms are usually fished for blackcod. The amount of time needed to set the groundline varies with weather and area conditions. Buoys and flagpoles, set at both ends of the groundline, identify gear and are essential to retrieval. Gangions (averaging 60 cm in length) are set approximately 101 cm apart with spacing varying considerably among vessels. Circular hooks (#6 to #8), which have higher catch retention, have recently replaced the older standard "J" hooks. Each skate of gear has approximately 200 hooks. Typically the hooks are baited with herring or squid. Gangions are attached to the longline by either halibut clips (metal clips) or beckets (woven pieces of line). Soak times

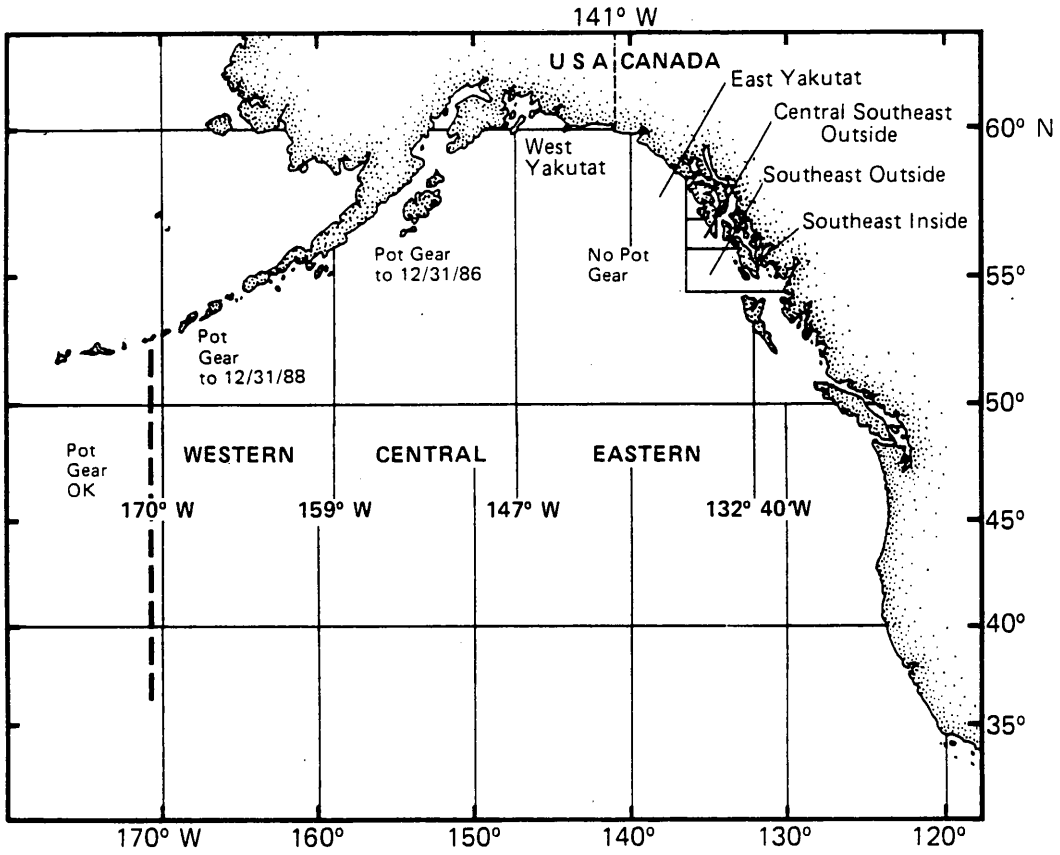

Figure 3.--Phase-out of Pot Gear in Alaskan Blackcod Fishery.

(gear on the bottom actively fishing) vary by area ranging from 4 to 24 hours. Damage to blackcod by "sand fleas" (small amphipods) can be severe with extended soak times in certain areas. Hydraulic winches aid in gear retrieval, with retrieval time varying considerably. Depending upon currents and bottom contours, groundlines can become tangled or snarled during fishing operations, thus significantly increasing retrieval times.

KILLER WHALE/BLACKCOD FISHERY INTERACTIONS

Prince William Sound

The following summary is principally based on contract reports submitted to NMML by Matkin (1986) and Matkin et al. (1987a). Killer whale depredation on longline caught blackcod was first reported from Prince William Sound during the 1985 fishing season. Matkin (1986) estimated that 25% of the 1985 Prince William Sound blackcod longline catch was lost due to killer whale depredation. In 1986, immediately after the 1 April opening, blackcod fishermen once again reported killer whales taking blackcod. Fishery interactions within Prince William Sound were localized and only occurred north of Knight Island (Fig. 4).

Although numerous killer whales seasonally inhabit Prince William Sound, only one resident pod was reported to be involved in the blackcod fishery interactions. This group, previously labeled as AB pod, consisted of 35 whales. Hall and Cornell (1986) documented that several members within AB pod showed evidence of bullet wounds. In 1985, three whales were reported missing from AB pod; in 1986, three additional whales were absent; and in 1987, another whale was missing. Between 1985 and 1987, a total of seven whales were listed as missing and presumed dead (Matkin 1988).

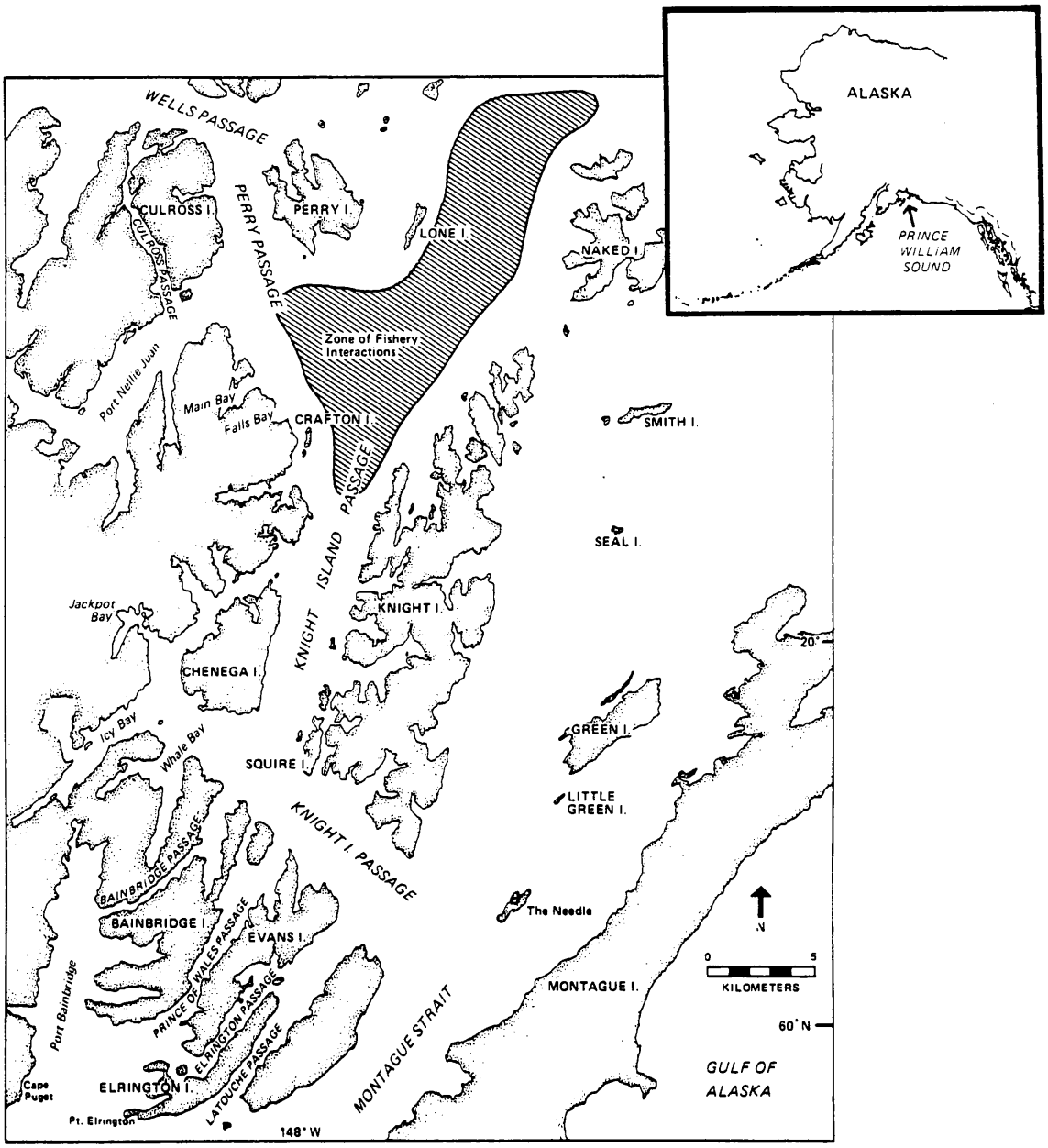

Figure 4.--Locations of Killer Whale/Blackcod Fishery Interactions in Prince William Sound.

During killer whale depredation, blackcod are consumed when groundlines are being retrieved. Frequently, only blackcod heads or "lips" remain as evidence of Orcinus predation (Fig. 5). Whole fish can show extensive rake marks made by killer whale teeth, which can reduce their commercial value. Catch per unit effort also declines in the presence of killer whales (resulting in a greater number of empty hooks). Occasionally, hooks were bent or straightened out. The condition of hooks, however, can not be cited as direct evidence of killer whale predation because hooks can become snagged on the bottom during normal operations. Initially (in 1985), the whales were observed moving into the area when the hydraulic winches were engaged to haul in the groundline. Fishermen believed that hydraulic noise transmitted through the water attracted the whales. In 1986, whales were reported to position themselves by the buoys apparently waiting for longline retrieval operations to begin. During interactions, whales were one-fourth to one-half mile from operating vessels, occasionally coming closer as the end of the groundline approached a boat. Depths of depredation are unknown; however, available data suggest that whales are not capable of feeding on fish when the longline is on the bottom.

Numerous methods have been employed by fishermen to either trick the whales or discourage them from stealing fish off the longlines (Table 2). In late summer of 1986, NMML received reports of fishing crews using high-power explosives to frighten whales away from their gear. Although fishermen believed that the explosive charges were responsible for whales leaving the area, confounding events (such as an increase in runs of salmon) may have contributed to the whales' departure from the area. Source levels and frequencies of the explosives used in Prince William Sound were

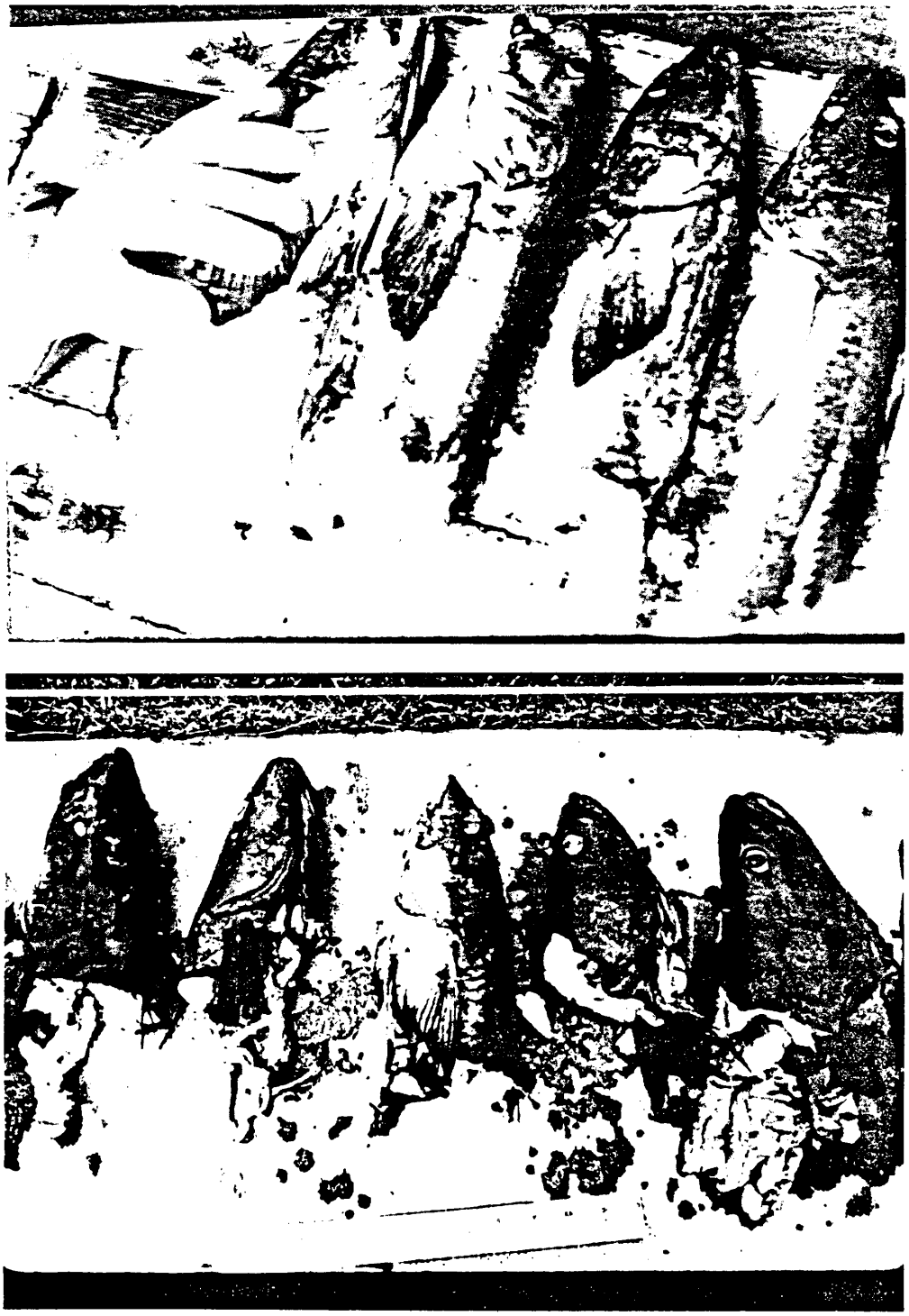

Figure 5.--Photographs of Bering Sea Blackcod Damaged by Killer Whales. Courtesy of: Jim Stark. National Marine Fisheries Service, Seattle, Wa.

Table 2.--Summary of methods employed to discourage whale depredation on longline catches (PWS = Prince William Sound and BS = Bering Sea).

Method	Area	Result	Comment
Seal bombs	PWS, BS	Not effective	Occasionally a startled response but whales did not leave area.
Decoy boats	PWS, BS	Not effective	Did not confuse whales.
Blank sets	BS	Not effective	Whales immediately returned to vessel with blackcod on lines.
Dummy buoys	BS	Some effect	Whales occasionally lost interest, left area.
Combined hauling	PWS	Not effective	Whales moved between vessels.
Stop operations	BS	Some effect	Occasionally helped.
Night fishing	BS	Not effective	No apparent difference.
Movements (short)	BS	Not effective	Movements < 60 nmi.
Movements (long)	BS	Some effect	If movements greater than 60 nmi were made, vessels could sometimes out run whales.
Change of target species	BS	Very effective	Switch to Pacific cod.
Shooting	PWS, BS	Not effective	Whales still in area.
Explosives	PWS	?	Not adequately tested.
Elect. currents	BS	Not effective	No other information.
Trap gear	BS	Very effective	No predation occurs.
Tangle imitator*	PWS	Not effective	Did not confuse whales.
Acoustic harassment device*	PWS	?	Not adequately tested.
Bang pipe*	PWS	Not effective	No apparent difference.

* = Research testing (blank sets and seal bombs included during test fishery).

investigated and subsequently described (Coastline Environmental Services, Ltd. 1987). During fall of 1986, the State of Alaska funded studies on methods to discourage whales from depredating on longline caught blackcod in Prince William Sound. Various methods were tried during this test fishery; however, none proved effective (Matkin et al. 1987b; Table 2).

The 1987 status of fishery interactions involving killer whales in Prince William Sound is summarized in Matkin (1988). The number of interactions and associated whale mortality were reduced during this season. Whales were not seen during the first week of the fishery. Scattered reports were received during the second week noting some fishery interactions. By the third week of April, whale interactions were negligible. No additional reports were received between April and June. The fishery closed on 25 June 1987.

In 1988, whale/fishery interactions in Prince William Sound were again documented. Attempts to discourage whales, using high-power explosive charges, were not successful (C. O. Matkin pers. commun.)[1].

Southeastern Bering Sea

Information pertaining to killer whale/blackcod fishery interactions in the Bering Sea were gathered from a variety of sources. Longline fishermen reported blackcod depredation by killer whales from Unimak Pass west to long. 172°30'W. The number of encounters with whales were reported to decrease just north of the Aleutian Islands. However, when approaching the waters south and west of the Pribilof Islands, the number of killer whale interactions increased (Fig. 6).

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[1] C. O. Matkin. North Gulf Oceanic Society, P. O. Box 15244, Homer, Alaska 99603. Pers. Commun, May 1988.

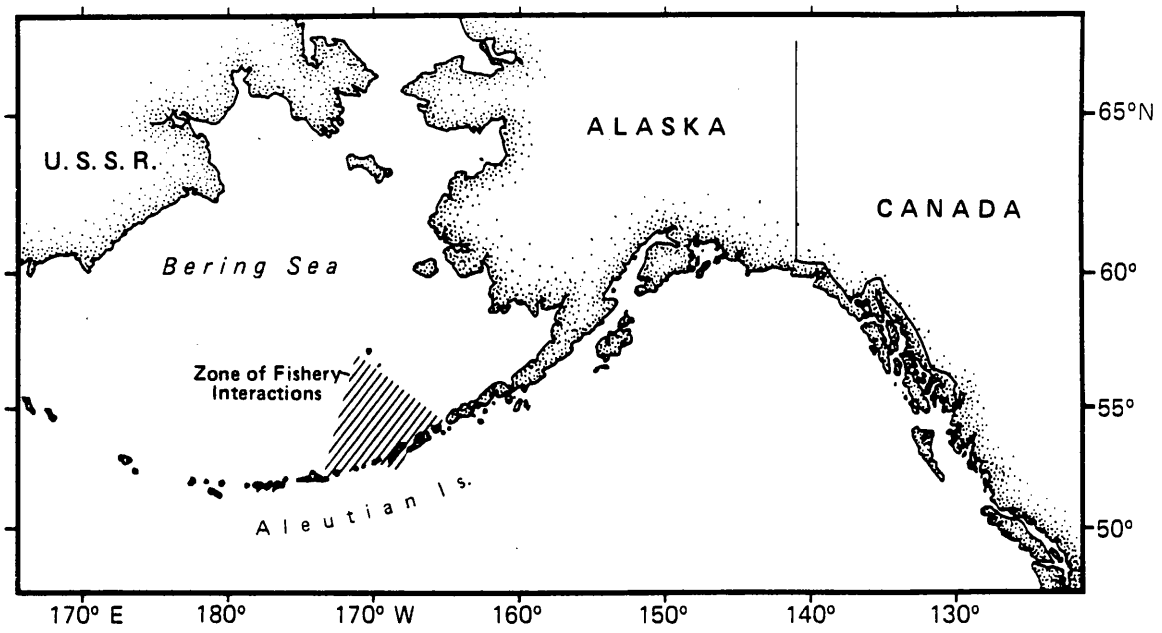

Figure 6.--Locations of Killer Whale/Blackcod Fishery Interactions in the Southeastern Bering Sea.

Whale behavior during fishery interactions in the Bering Sea was similar to that described in Prince William Sound. When using pot gear, whales were not considered to be a problem. Bering Sea fishermen stated that lower predation rates on blackcod by killer whales occurred when their longlines became snarled, despite the fact that fish were still easily accessible. A tangled or snarled groundline would not only present a large visual stimulus to a whale but it could also provide an active acoustical feature. As the line is retrieved, the variable tension on the line can cause snapping or popping. Perhaps whales avoid these tangled sections of line because: 1) the line recovery sounds may elicit an avoidance response, 2) the physical rearrangement of the lines may cause confusion, and 3) whatever cue the whales use to select specific fish species from the line is interrupted or destroyed (e.g., the fish no longer move in the same way). During fish detection, whales may rely on active echolocation, passive listening, or vision (at close range). The environmental cues and sensory mechanisms used by whales to locate fish during fishery interactions are not known.

Reports were available from U.S. observers working aboard 27 Japanese commercial longline vessels in Alaskan waters from 1977 to 1985. Fishing occurred from the Canadian/Alaskan border (southeast Alaska), through the Gulf of Alaska, into the Aleutian Islands and southern Bering Sea. Information pertaining to fishery interactions involving killer whales was extracted and summarized.

Every vessel within the Japanese fleet reported fishery interactions with killer whales, with all interactions confined to the Bering Sea. There were 56 reports available documenting depredation by killer whales on

longline catches, representing 15% of 365 trips. Depredation of blackcod by whales occurred throughout the year. Since the consistency of reporting is not similar from year to year, an increasing/decreasing trend of killer whale depredation on longline blackcod cannot be determined.

In addition to blackcod, U.S. observers also reported killer whales taking longline catches of greenland turbot (Reinhardtius hippoglossoides) and arrowtooth flounder (Atheresthes stomias). Pacific cod (Gadus macrocephalus), grenadier (Coryphaenoides acrolepis), and rockfish (Sebastes spp.) were never consumed. No information is available on the behavior and the number of whales involved in the interactions or the amount of fish taken. Japanese captains and fishing masters were well aware of killer whales taking blackcod (as well as other groundfish) in the Bering Sea and would avoid areas where killer whales were reported. Numerous methods were tried to discourage the whales (Table 2), but only stopping operations, long-range vessel movements (greater than 60 nmi), and changing the target species to Pacific cod were considered effective.

Beginning in 1978, under a cooperative research agreement with Japan, NMFS scientists have participated in data collection activities aboard Japanese longline research vessels. Surveys begin in early May and continue through August. Areas surveyed include the Aleutian Islands into the Bering Sea, Gulf of Alaska, and waters of southeast Alaska (Fig. 7). Weather permitting, the vessel works a station per day, setting out approximately 9 nmi of groundline generally between the 100 and 1,000 m isobaths.

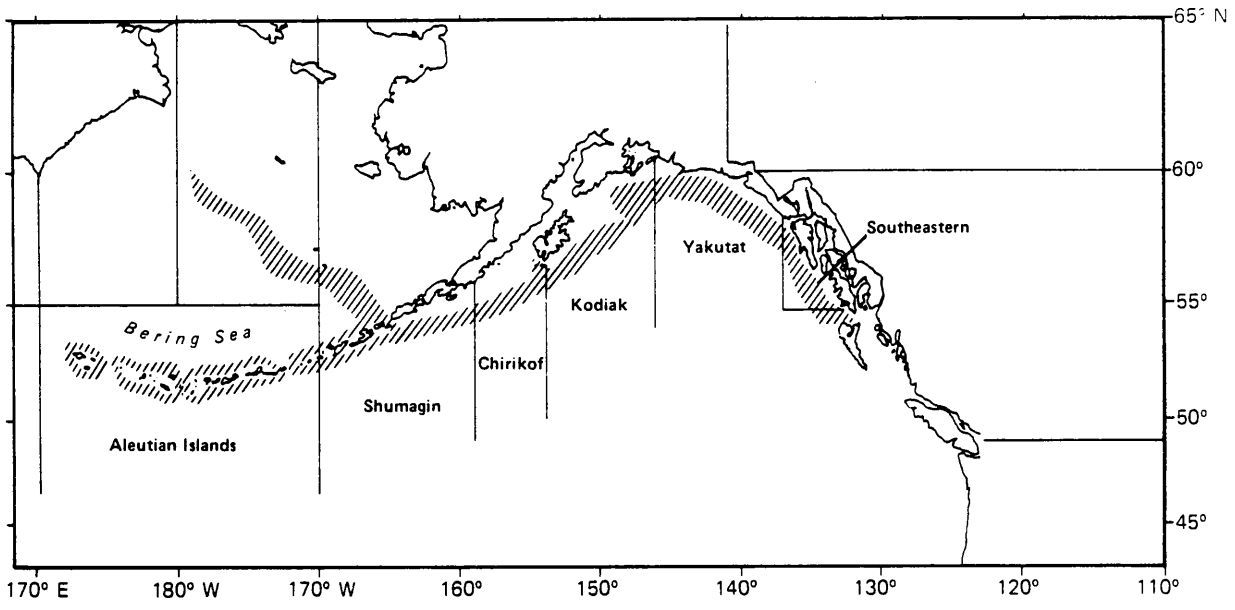

Figure 7.--Survey Positions of Japan-U.S. Joint Longline Research in Alaska. Courtesy of: T. Sasaki. Far Seas Fisheries Research Laboratory, Shimizu 424 Japan.

Fishermen first reported interactions with killer whales in 1980, when Japan expanded the longline research into the Bering Sea. Accounts of killer whales depredating blackcod were recorded each year from 1980 through 1987 with the number of encounters varying per year. Japanese scientists stated that killer whales were known to interfere with longline operations in the Bering Sea as far back as the 1960's (T. Sasaki pers. commun.)[2]. In 1986, 1987, and 1988 NMML requested that specific data pertaining to killer whales be collected during research cruises to include: location, date, number of whales observed, any characteristic scars or deformities on whales (photographed when possible), and an assessment of the impact on the fisheries. In 1987, a U.S. vessel participated for the first time in these longline research surveys providing additional information.

NMML also requested that personnel aboard NOAA vessels collect photographs of Alaskan killer whales when possible. In 1986, 191 photographs were taken of Bering Sea killer whales. In 1987, 594 photographs were collected. NMML is continuing photographic efforts in 1988 as well. All photographs are sent to the Pacific Biological Station in Nanaimo, British Columbia, Canada, where comparisons are made to photographs of killer whales taken throughout the North Pacific. Within- and between-year matches have been found in the Bering Sea. Matches between Bering Sea killer whales and whales from other Alaskan areas have not occurred.

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[2] T. Sasaki. Far Seas Fisheries Research Laboratory, 7-1, 5-Chome Orido, Shimizu 424 Japan. Pers. Commun, 26 June 1986.

In 1988, NMML initiated dockside interviews at Dutch Harbor, Alaska. The blackcod longline fishery consisted of 12 vessels during this winter season. Between 8 and 22 February, six commercial longline fishermen were interviewed. In March, two additional dockside interviews were completed. Fishing efforts (representing a total of 147 days) had been concentrated south of the Pribilof Islands and between Akutan Island and the Islands of Four Mountains. Fishermen set an average of 2.4 lines per day with a mean of 17.5 skates per line. The number of hooks per skate ranged from 180 to 225 with a mean of 200, representing an average of 3,500 hooks per line. Soak time typically ranged from 4 to 24 hours, with 6 to 11 hours most common. Trip duration depended on vessel size and weather conditions, ranging from 6 to 31 days. Seventy percent of the catch was blackcod.

All of the fishermen who were interviewed (representing 50% of the winter longline fleet) reported that killer whales interfered with fishing operations during the months of January, February, and March. Occasionally, two or three vessels separated by many miles simultaneously reported whales depredating blackcod caught on longlines. This suggests that several pods were involved. Pod size ranged from 3 to 25 individuals. Fishermen believed that they could identify many of these whales based upon characteristic scars or dorsal fin shapes.

Whales interacted with fishermen in 6 to 50% of the sets (mean = 20%). The amount of money lost per day by a single fishing vessel during the 1988 winter season based on the estimated number of fish lost per set when killer whales were present averaged $2,293 (with a low of $250 and a maximum of $5,000). If the amount of time lost either waiting for

whales to leave or moving the vessel away from the whales is considered, then the estimated dollars lost per day would increase.

Most fishermen stated that shooting, seal bombs, and other techniques were ineffective means of driving the whales away. Of particular interest was the use of partial longline gear consisting of dummy buoys set in the presence of killer whales. An anchor with an ample supply of line was connected to a surface buoy. Three "dummy buoys" were set at 5- to 10-mile intervals in the general vicinity of the fishing grounds. When killer whales appeared, the actively fishing longline was cut, and the vessel immediately went to retrieve the dummy buoys. After retrieval of buoy number one, the vessel moved on to retrieve the second dummy buoy, and then onto the third. Occasionally whales lost interest and would leave the area. Whales have also been known to lose interest when operations shut-down for short periods of time (4 to 6 hours) but this method was not always effective.

Although not quantified, most fishermen believed that the number of interactions between whales and longline operations increased following the closure of the joint venture trawl fishery. The concensus of interviews indicated that incidents with killer whales were increasing, and commercial fishermen were becoming increasingly more frustrated. All of the fishermen expressed the need for research into ways of alleviating these fishery interactions. Possible methods to help reduce or eliminate killer whale depredation of longline-caught blackcod have been discussed several times among agencies and individuals involved in this particular issue; the possible methods are summarized in Table 3. Proper experimentation is needed to reveal the effectiveness of these various methods.

Table 3.—Possible methods to help reduce or eliminate killer whale depredation on longline caught blackcod.

Method	Comment
Sparker devices	Attached to gangion; emits flash of light and transient sound to startle whales.
Rubber bullets	Irritant to whales.
Electrical current	Electrical shock to whales.
Masking of sounds	Interference of acoustical stimulus responsible for attracting whales to vessel.
Playback sessions	Recorded sounds from longline operations reproduced into water. No food reward associated with attraction to vessel sounds.
Bubble screen	Interference with active/passive acoustical sense or vision of whales.
Accessory skiffs	Deployed from main vessel into vicinity of whales causing possible visual and acoustical harassment.
Sonic devices	Acoustic harrassment in frequency range that would be sensitive to whales' hearing.
Lithium cloride/ether	Strong emetic producing vomiting reaction.
Operant conditioning	Behavioral modification of whales. Weak signal precedes strong, aversive signal.
Management solutions	a) Gear modification; b) pot gear; c) seasonal restrictions (fishing in an area when killer whale density may be low); d) actual fishery closure in areas with high levels of predation.
Multiple/cumulative	Various combinations of above.

DISCUSSION

Killer whale depredation on longline-caught blackcod occurs throughout a wide area in the southeastern Bering Sea (Fig. 6). Most of these interactions occur close to land or on the continental shelf break. In Prince William Sound, problems with killer whales were more localized (Fig. 4). When areas of interactions are compared to the whale distribution plot in Figure 1, it is clear that the blackcod fishery occurs in an area of high killer whale density.

Every Bering Sea fisherman interviewed had experienced interactions with killer whales during longline operations. Available information suggests that several pods of killer whales are involved in these interactions. Preliminary evidence implies that similar pods are consistently responsible for depredation activities on longline-caught blackcod in the Bering Sea. Evidently, some pods of whales just pass through the fishing area and are not attracted to longline operations. Whale interactions are documented during the winter fishery (January through March) as well as the summer/fall period (June through September). A review of the available Japanese data indicated that interactions occurred every month of the year, suggesting year-round occurrence by killer whales.

Available data are not sufficient to assess whether or not an increasing trend in killer whale/blackcod fishery interactions is occurring in Alaska. Whale depredation on Bering Sea blackcod caught on longline gear occurs on 20% of the sets, based on calculations made during the 1988 winter season. This predation rate costs fishermen an average of $2,300 per day in lost fish (which could vary significantly given differences in

seasonal rates of predation). Rates of interactions may vary among vessels with the smaller catcher boats (which are not capable of long-distance movements) experiencing more problems with whales. A vessel emitting a distinctive noise signature may also have higher predation rates if whales learn to associate specific sounds with food.

Fishery interactions involving killer whales are not unique to Alaska. Off Iceland, killer whales have been known to interfere with the herring fishery. In Norwegian waters, killer whales have been known to take halibut off longline gear. In the North Atlantic, fishermen reported killer whales taking tuna off their longlines. Killer whales have also been reported to take tuna caught during longline operations off Japan (T. Sasaki, footnote 2). Interactions between killer whales and longline tuna fishing have been documented in the Indian Ocean (Leatherwood et al. 1987). Off Tasmania, killer whales have been known to depredate trevalla (Hyperoglyphe porosa) caught in the drop-line fishery (Tasmanian Fisheries Development Authority 1981). An assessment of damage incurred was not given in the above accounts and it was not clear if there was a final resolution to the problem. Recently, sperm whale (Physeter macrocephalus) depredation of longline-caught blackcod has been documented in the Gulf of Alaska (reports to NMML from NOAA personnel in 1986, fishermen and biologists from the domestic observer program in 1988).

Three important factors must be properly evaluated when considering methods to reduce or eliminate marine mammal/fishery interactions: 1) the adverse effect on the mammals, 2) the adverse effect to the fishery, and 3) the feasibility of the method being used in the fishery (gear, costs, etc.). Killer whale depredation behavior on longline-caught blackcod is

constantly being positively reinforced by food. Food represents the strongest reward known for shaping an animal's behavior. To alleviate these interactions would require a high level of effort or harassment and a long-term commitment to properly reshape, if possible, the present behavior of killer whales. If several pods are involved, this would further complicate the effort.

Methods that are effective in reducing or eliminating killer whale depredation on longline-caught blackcod should continue to be used and expanded upon where and when possible. These methods include: dummy buoys, long-distance movements, temporary cessation of fishing operations, changing target species of directed fishery, and the use of pot gear. The National Marine Mammal Laboratory will continue to collect information regarding killer whale fishery interactions in Alaska focussing on the impact on the fishery, number of killer whale pods involved, and possible ways to reduce or eliminate whale predation on longline caught blackcod.

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