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A Review of Cetacean and Pinniped Mortality in Coastal Fisheries Along the West Coast of the USA and Canada and the East Coast of the Russian Federation

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ABSTRACT

Many passive net fisheries exist along the Pacific coastlines of the USA (California, Oregon, Washington and Alaska), Canada (British Columbia) and the Russian Federation. Some incidental marine mammal mortality occurs in almost all of these fisheries. In this report, we examine 14 of the fisheries from this region that cause marine mammal mortality. The reviews include: (1) a discussion of the relevant laws pertaining to marine mammal mortality in fisheries in each of the three countries, (2) a brief synopsis of the target species and the area and method of operation for the fishery, (3) information on the economic importance of the fishery and the size of recent catches and (4) any available information on the levels of take of cetacean and pinniped species. Less complete, sometimes anecdotal information is provided for a number of other fisheries in this area. For the vast majority of all coastal fisheries along the North Pacific rim, insufficient information is available to determine whether the fisheries are having a negative impact on the species of marine mammals that live in this area. Based on our findings for this area, we make four recommendations for the gathering of additional information to evaluate the significance of fishery mortality on marine mammal populations and to help minimize its impact.

KEYWORDS: NORTH PACIFIC; INCIDENTAL CAPTURE; FISHERIES; MANAGEMENT; GRAY WHALE; COMMON DOLPHIN; MINKE WHALE; NORTHERN RIGHT WHALE DOLPHIN; SHORT-FINNED PILOT WHALE; RISSO'S DOLPHIN; BOTTLENOSE DOLPHIN; SPERM WHALE; DALL'S PORPOISE; PYGMY SPERM WHALE; PACIFIC WHITE-SIDED DOLPHIN; KILLER WHALE; HUBBS' BEAKED WHALE; CUVIER'S BEAKED WHALE; WHITE WHALE; SEALS.

INTRODUCTION

Increasing international attention is being focused on the problem of incidental mortality of marine mammals in gillnets and other fishing gear. Evaluating the significance of this problem has been hampered by a lack of information regarding (1) which marine mammals are being taking in which fisheries, (2) how many marine mammals are being taken and (3) the size of the marine mammal populations. Rarely is complete information available for all three. In this review we will attempt to provide information on the first of the above categories. We limit ourselves largely to gillnets and other passive fishing gear. We will concentrate on cetaceans caught in the coastal fisheries of the western USA, western Canada and eastern Russia, and will provide quantitative estimates of kill rates where available. Where available, we will also provide information on mortality of pinnipeds and sea otters. In very few cases has the total marine mammal mortality been estimated. In even fewer cases have

cetacean population sizes been estimated. Clearly we are a long way from being able to evaluate the significance of marine mammal mortality in fisheries.

Cetacean mortality in passive fishing gear is largely limited to gillnets. Gillnets are commonly classified as set nets (nets that are anchored to the bottom) and driftnets (nets that are free-floating). Both types of nets can be fished at the surface or in mid-water. Only set nets are commonly fished at the bottom. Within the general category of gillnets we include trammel nets, suspendered gillnets and other entangling nets. We will also consider traps and discarded fishing gear (including gillnets and trawl nets) as passive fishing gear.

For consistency and comparability, we have converted units of measure to a common system. We use metric measures of length and mass and US dollars for the value of fish catches. Some small errors may be introduced by these conversions. For consistency, information on fisheries will be presented in geographical order starting with southern California and proceeding counter-clockwise around the Pacific rim to southeastern Russia. A list of common and scientific names used in this report is given in the Appendix.

The fisheries to be considered in detail are given in Table 1 and their approximate locations are shown in Fig. 1. We specifically exclude the North Pacific high-seas driftnet fisheries for squid, tuna and salmon which are covered in separate reports (Hayase *et al.*, 1990; Nagao, 1994; Watanabe, 1994; Yatsu, 1994).

Table 1

Fisheries considered in detail in this report.

(A)	the driftnet fishery for sharks and swordfish off California
(B)	the setnet fisheries off California
(C)	the gillnet fishery for salmon in Washington state
(D)	the driftnet fishery for salmon off British Columbia
(E)	a Canadian-sponsored experimental driftnet fishery for flying squid in western Canadian waters and adjacent international waters
(F)	the salmon setnet fishery in Yakutat and driftnet fishery in southeastern Alaska
(G)	the setnet and driftnet fisheries for salmon in the Copper River Delta and Prince William Sound, Alaska
(H)	the driftnet fishery for salmon in Cook Inlet, Alaska
(I)	the setnet and driftnet fisheries for salmon off Kodiak, South Unimak, and the Alaska Peninsula
(J)	the pollock trawl fishery in the Bering Sea/Gulf of Alaska
(K)	the setnet and driftnet fishery for salmon in Bristol Bay, Alaska
(L)	the setnet fisheries in northern Alaska
(M)	the driftnet fishery for salmon off eastern Russia
(N)	the trapnet fishery for salmon off eastern Russia

LEGAL FRAMEWORK

In the USA, all marine mammals are managed under the Marine Mammal Protection Act (MMPA) of 1972 (as subsequently amended). Prior to 1988, incidental mortality in fisheries was permitted if the populations could be shown to be within a range of 'optimum sustainable population' size (OSP). OSP was interpreted to be a population size between the maximum net productivity level and the environmental carrying capacity. However, OSP has not been determined for most of the cetacean species in US coastal waters. In the 1988 amendments to the MMPA, a special exemption program eliminated the OSP requirement for a 5-year period, during which studies were to be undertaken to assess the status of marine mammal populations and the levels of incidental taking in fisheries. Any fisherman receiving a certificate of exemption was allowed to take marine mammals incidental to their fishing activities regardless of the population's OSP status (although still subject to provisions of the Endangered Species Act). The 1994 amendments to the MMPA established a protocol for setting limits on the maximum allowable takes from each marine mammal population to be in place by January 1995.

Both the 1988 and 1994 amendments provided for an observer program to monitor marine mammal mortality in those fisheries with the highest take rates. The US National Marine Fisheries Service (NMFS) has administered these observer programs, either directly or through contracts.

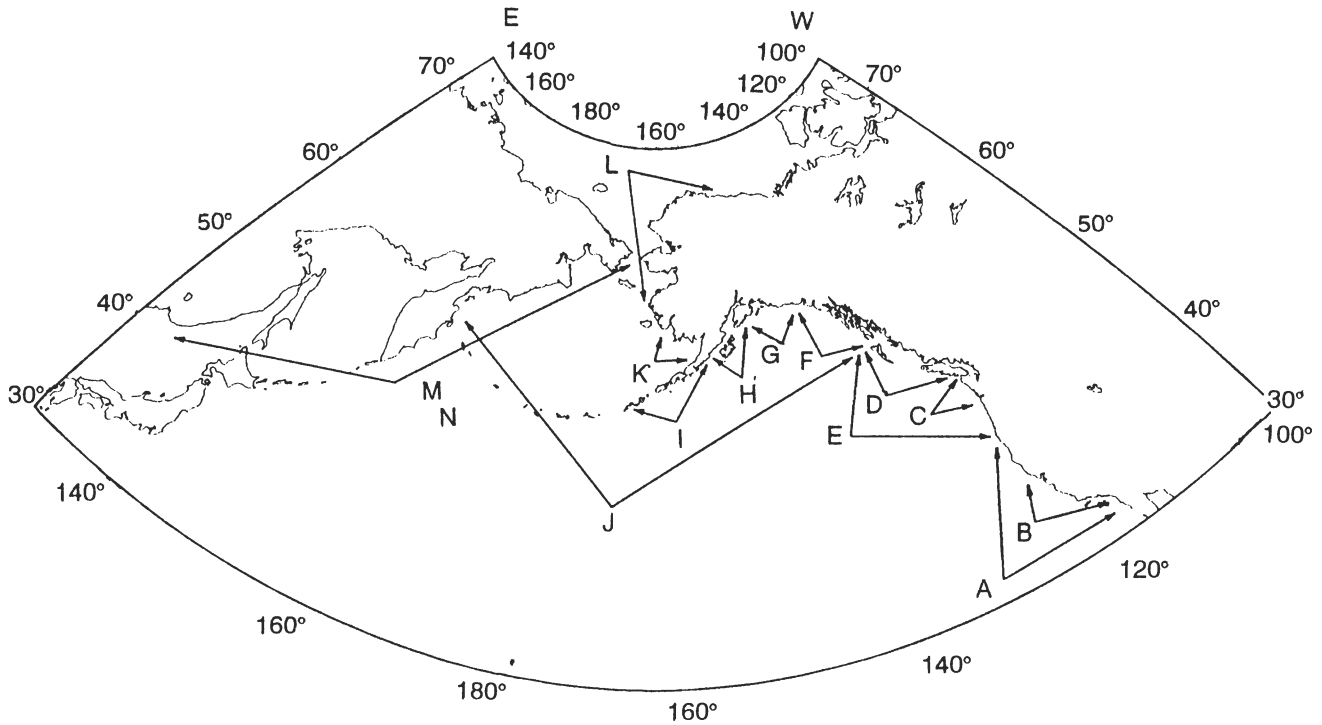

Fig. 1. Approximate location of fisheries considered in detail in this report. Letters refer to Table 1.

In addition, fishermen are required to submit 'logbook' reports detailing all takes of marine mammals in all fisheries that have greater than a 'remote' likelihood of killing marine mammals.

In Canada, marine mammals are protected from all but aboriginal hunting by the 1993 Marine Mammal Regulations of the Fisheries Act of Canada of 1867. Aboriginal hunting can be undertaken for most species without a licence, but only for food, social or ceremonial purposes. Disturbance of marine mammals under these regulations is prohibited, but no definition of 'disturbance' is given. In the case of incidental catches, fishermen are neither encouraged nor required to report catches. When catches are reported, no action is taken.

In the fisheries economic zone of the former USSR, rules stated that incidental catches (including marine mammals) were limited to a maximum of 8% of the total catch by numbers of individuals. If the combined numbers of non-target fish and marine mammals exceeded 8% of the total catch, fishermen were required to move to another area. Fishermen were not punished for incidental catches of cetaceans, but were required to document in their fishing logs the incidental catch of all marine mammal species. In fact, these data were never reported by fishermen or fisheries agencies.

SYNOPSIS OF THE FISHERIES

(A) California driftnet fishery for sharks and swordfish

The driftnet fishery for pelagic sharks began off southern California about 1977 (Hanan *et al.*, 1993). Initially, swordfish were caught incidentally and regulations limited swordfish to no more than 25% of the total catch (Miller *et al.*, 1983). This regulation was later modified and fishermen now fish for both sharks and swordfish (subject to seasonal and area closures) (Hanan *et al.*, 1993). Marine mammal mortality in California gillnets was first documented by Miller (1981). A gillnet observation program was initiated by the California Department of Fish and Game (CDFG) to evaluate the level of marine mammal bycatch in this fishery; this program was discontinued in the late 1980s. A NMFS observation program was initiated in June 1990 and continues today.

Primary ports

The primary ports are San Diego and San Pedro, CA.

Target species

The target species are swordfish, thresher shark, mako (bonito) shark and opah.

Area of operation

The area of operation comprises offshore waters from the Mexican border to Washington, within the US EEZ, principally encompassing sea mounts, escarpments and banks of the continental shelf. The fishery expanded from California to offshore Oregon and Washington, but landings were prohibited in Oregon and Washington due to high incidental catches of marine mammals.

Vessels and crew

Vessels are typically 9–23m long and are made of steel, fiberglass or wood. There are approximately 235 permitted vessels statewide. Of these, currently only about 150 permits are active. Fish are typically held on ice or in brine spray, but a few boats have refrigeration. Crews are typically 2–6 US fishermen.

Gear specifications

Monofilament and 3-strand nylon gillnets are used, with a stretched mesh size of 46–61cm (with an average of 48cm). Nets range from 915–1,830m long by 50–100 meshes deep (mean depth is 40m with a range of 27–62m). The top of the net is typically fished 5–27m below the surface. Surface floats are 30cm in diameter and are spaced 18m apart. The ends of the nets are marked with light beacons and a 25cm radar reflector. Nets are hauled with net reels.

Operations

Trips are typically 1–14 days long and may not end in the same port they begin. Vessels fish one net per night and stay attached to the net. Nets are set in water depths of 122–610m and are free to drift. Nets are set 2hrs before sunset and must be completely hauled by 2hrs after sunrise. Retrieval time is typically 2–4hrs. The fleet typically follows the highest concentrations of fish. The fishery is closed within 75 miles of the coast during the gray whale migration.

Economics and history

The ex-vessel prices range from $4–10/kg for swordfish, $2–4/kg for shark and $0.50/kg for opah. Fish are sold fresh or frozen in the domestic market. The total values of the landings were approximately $5,000,000 for swordfish and $2,000,000 for sharks circa 1990. The fishery developed in the late 1970s, peaked in the 1980s and is now declining.

Total landings

Total landings in 1990 were 680 tonnes of swordfish and 370 tonnes of shark (Hanan *et al.*, 1993).

Effort data

Effort decreased from about 10,000 net pulls per year in the mid 1980s to about 5,000 in recent years (Table 2).

Interactions with cetaceans

Marine mammal mortality was monitored in the mid-1980s by a CDFG observer program and since 1990 by a NMFS observer program. Entangled species included gray whales, short-beaked common dolphins, minke whales, northern right whale dolphins, short-finned pilot whales, Risso's dolphins, bottlenose dolphins, sperm whales, beaked whales, Dall's porpoise, pygmy sperm whales and Pacific white-sided dolphins (Table 2). Evidence of entanglement was also found on beach-cast specimens of short and long-beaked common dolphins, bottlenose dolphins, Risso's dolphins, Pacific white-sided dolphins, killer whales, a Hubbs' beaked whale and a Cuvier's beaked whale (Heyning *et al.*, 1994). Total annual mortality for cetaceans was not estimated by CDFG due to insufficient sample size, but observed mortality is summarized in Table 2. Using data from the CDFG driftnet observation program and extrapolating to the 99% of sets that were unobserved, Heyning and Lewis (1990) provided a rough estimate that 441 rorqual whales were taken in driftnets between 1980–85 with an annual take of about 73 rorquals. If animals are small, they are brought aboard, but whales are usually cut out at the water line. Entangled cetaceans are usually dead, but one minke whale and one sperm whale were released alive. Table 2 provides observed and estimated total mortality from the 1990–93 NMFS Observer Program.

Table 2

Observed and estimated fishing effort and marine mammal mortality in California's drift gillnet fishery for swordfish and sharks from the 1980 to 1986 CDFG observer program (Miller *et al.*, 1983; Diamond *et al.*, 1987; Hanan *et al.*, 1988; Hanan and Diamond, 1989; Konno, in press) and the 1990 to 1993 NMFS observer program (Lennert *et al.*, 1994; Perkins *et al.*, 1992; Julian, 1993; 1994). Missing data indicate no available estimates.

	Observation period								
From	4/80	4/83	4/84	4/85	4/86	7/90	1/91	1/92	1/93
To	3/83	3/84	3/85	3/86	3/87	12/90	12/91	12/92	12/93
Effort									
Est. no. net pulls	14,140	11,000	9,700	10,000	10,330	4,078	4,752	4,504	6,599
No. observed net pulls	226	71	44	66	0	181	470	595	728
% observed net pulls	1.6%	0.6%	0.5%	0.7%	0.0%	4.4%	9.9%	13.2%	11.0%
Observed marine mammal mortality									
Unid beaked whale	0	0	0	2	-	0	0	3	0
Common dolphin	0	0	3	7	-	9	44	47	28
Minke whale	0	0	1	0 [1]	-	0	0	0	0
Northern right whale dolphin	0	0	0	1	-	0	7	15	7
Short-finned pilot whale	2	0	0	0	-	1	0	1	11
Pac. white-sided dolphin	1	0	0	0	-	3	5	3	2
Dall's porpoise	0	0	0	0	-	1	2	1	9
Risso's dolphin	-	-	-	-	-	0	5	5	4
Cuvier's beaked whale	-	-	-	-	-	0	0	6	3
Mesoplodont beaked whale	-	-	-	-	-	1	0	3	0
Bottlenose dolphin	-	-	-	-	-	0	0	3	0
Sperm whale	-	-	-	-	-	0	0	3	3 [3]
Pygmy sperm whale	-	-	-	-	-	0	0	0	1
California sea lion	82	6	1	1	-	4	4	9	12
Harbor seal	0	0	0	1	-	1	0	0	0
Elephant seal	0	2	0	2	-	4	13	15	14
Steller sea lion	-	-	-	-	-	0	0	1	0
Estimated marine mammal mortality									
Unid. beaked whale	-	-	-	-	-	0	0	23	0
Common dolphin	-	-	-	-	-	203	373	356	207
Minke whale	-	-	-	-	-	0	0	0	0
Northern right whale dolphin	-	-	-	-	-	0	59	15	52
Short-finned pilot whale	-	-	-	-	-	23	0	8	81
Pac. white-sided dolphin	-	-	-	-	-	68	42	23	15
Dall's porpoise	-	-	-	-	-	23	17	8	67
Risso's dolphin	-	-	-	-	-	0	42	38	30
Cuvier's beaked whale	-	-	-	-	-	0	0	45	22
Mesoplodont beaked whale	-	-	-	-	-	23	0	23	0
Bottlenose dolphin	-	-	-	-	-	0	0	23	0
Sperm whale	-	-	-	-	-	0	0	23	22
Pygmy sperm whale	-	-	-	-	-	0	0	0	7
California sea lion	5,130 [2]	917	232	157	129	90	34	68	89
Harbor seal	0	0	0	158	90	23	0	0	0
Elephant seal	-	-	-	-	-	90	110	114	103
Steller sea lion	-	-	-	-	-	0	0	8	0

[1] One minke whale was caught and released alive.
[2] 1980-82 California sea lion kill was extrapolated from observed mortality and given percentage of observed sets.
[3] One sperm whale was released alive.

Pinniped bycatches and other information

Pinniped mortality information is also given in Table 2. California sea lions and elephant seals were the most common pinnipeds taken. Populations of sea lions, harbor seals and elephant seals are growing in California, despite fishery mortality.

Discussion

Reliable population estimates are now available for most of the cetacean species that are taken in this fishery (Barlow, In press). The estimated annual take rates exceed 2% of the population for several species and may not be sustainable.

(B) California set net fisheries

In California, halibut fishing with gillnets increased dramatically in the 1970s and early 1980s (Methot, 1983; Barlow, 1987). These increases were accompanied by a concurrent increase in the rate at which harbor porpoises (Szczepaniak and Webber, 1985) and seabirds (Salzman, 1989) washed ashore in the vicinity of San Francisco. Similarly, a set net fishery for angel sharks developed in southern California in the 1970s and 1980s. CDFG began observing set gillnets in central and southern California and confirmed that marine mammals were being entangled in the halibut fishery, as well as in fisheries for sharks and white seabass (Miller *et al.*, 1983). The CDFG observer program was largely discontinued in the late 1980s and was supplanted in 1990 by a mandatory NMFS observation

program in the set net fisheries for halibut and angel sharks. Set net fisheries for white seabass, yellow tail, soupfin shark, white croaker, bonito and flying fish are not observed regularly.

Primary ports
The primary ports are San Diego, Oceanside, Dana Point, San Pedro, Port Hueneme, Ventura, Santa Barbara, Port San Luis, Morro Bay, Monterey, Moss Landing, Half Moon Bay, San Francisco and Bodega Bay.

Target species
The target species are halibut, angel shark and white seabass.

Area of operation
The area of operation comprises near-shore mainland and insular areas from the Russian River to the Mexican border, typically in waters less than 55m deep.

Vessels and crew
Vessels are 4–12m in length and made from wood or fiberglass. The fleet size is limited to 200 permits, 134 of which were active in 1993. Fish are typically kept on ice and are often landed each day. Crews consist of 1–3 US fishermen.

Gear specifications
Nets are monofilament, twisted monofilament or multifilament nylon with stretched mesh sizes of 20–21cm. Panels are typically 275–366m long by 20 meshes deep. Nets are floated with either a buoyant cork line or with 5cm corks every 1 or 2m. Nets are typically marked at each end with a float or with a pole and flag. Nets are hauled by hand or with a hydraulic net reel.

Operations
Trips range from 1 day (most common along the mainland) to 1 week (most common at the Channel Islands). Fishermen often fish 3–5 separate 1-panel nets. Nets are set in waters less than 91m and usually less than 55m deep. Nets are set along the bottom and are tended in the early morning. Net retrieval takes 1–2hrs. Soak times are usually 24–48hrs. Typical catches are 3–10 halibut or 10–20 angel sharks per net.

Economics and history
Ex-vessel prices range from $5/kg for halibut to $1/kg for angel sharks. Fish is sold domestically, either fresh or frozen. The net values of the landings were $2,750,000 for halibut and $2,600 for angel shark circa 1990. The set net fishery in California developed first for white seabass. This fish stock is now severely depleted in California (Methot, 1983). Set net fishing for halibut expanded in the 1970s and was followed by development of the angel shark fishery.

Total landings
Total landings in 1989 were 545 tonnes of halibut and 1 tonne of angel shark.

Effort data
In California, the number of net sets has decreased from approximately 39,000 annually in the mid-1980s to approximately 16,000 in recent years (Table 3). Much of this reduction in effort is attributed to area closures to protect marine mammals, sea birds and sport fisheries.

Interactions with cetaceans
Harbor porpoises, gray whales, Pacific white-sided dolphins, common dolphins and possibly bottlenose dolphins have been observed entangled in set nets in California. Harbor porpoise mortality in the central California halibut fishery was estimated as approximately 200–300 per year in 1983–87 and has averaged about 40 per year since 1987 (Table 3). Accurate estimates have not been made for 1989, but the minimum mortality was 53 harbor porpoises in this fishery: 38 observed deaths plus 15 stranded animals with gillnet marks (Jefferson *et al.*, 1994). One harbor porpoise was observed caught in a white croaker gillnet out of the 200 net-pulls that were observed off central California (Hanan, unpublished data). Earlier reports also mentioned the entanglement of six harbor porpoises in white seabass gillnets near Morro Bay, California. Although white seabass is no longer common in that area (Methot, 1983), Barlow (1987) speculates that harbor porpoises in central California could have been depleted by the large-scale seabass gillnet fishery in the 1950s. Gray whale mortality has been estimated as less than 10 per year, mostly occurring in southern California (Heyning and Dahlheim, In press). Heyning and Lewis (1990) document 65 records of the entanglement of baleen whales in southern California waters during the 1980s, most of which are attributed to gray whales entangled in this set net fishery. Gray whales appear most likely to be entangled in nets that are set at headlands during their northbound migration. Dead cetaceans are either brought aboard or are cut out of the nets at the water line. Live entangled gray whales typically take the net with them. Some gray whales have been freed by the removal of netting and attached lines.

Time and area closures have reduced the total level of fishing effort in the harbor porpoise range and presumably the level of incidental take. Current legislation will close waters inshore of 55m throughout the sea otter range, approximately from Waddell Creek to Point Sal. In California, a gillnet ballot initiative passed in November 1990 will result in a buy-out of set nets and the elimination of gillnet fishing within 3 n.miles of the mainland and 1 n.mile of any island in southern California by 1994. Preliminary data indicate that some fishing continues in deeper waters. Efforts have been made to reduce whale mortality by use of break-away panels, increased bridle strength and anchor weight, and decreased cork-line strength.

Local populations of harbor porpoises may have been reduced to less than 50% of their pre-fishery abundance in central California (Barlow, 1987; Barlow and Hanan, 1994). The gray whale population is continuing to increase (IWC, 1993; Buckland and Breiwick, In press).

Pinniped bycatches and other information
California sea lion mortality in this fishery has been approximately 2,000–4,000 per year and the harbor seal mortality has been 500–2,000 per year (Table 3). Populations of both species (and elephant seals) are growing in California despite this fishery mortality.

Discussion
Good information is available on the abundance and status of all species of cetaceans and pinnipeds in California waters. In fact, information on the impact of fishing mortality on marine mammal populations may be better for this fishery than for any other gillnet fishery.

Table 3

Observed and estimated fishing effort and marine mammal mortality in California's set gillnet fisheries for halibut and angel sharks from the 1983 to 1988 CDFG observer program (Diamond and Hanan, 1986; Hanan *et al.*, 1986; Hanan *et al.*, 1987; Hanan *et al.*, 1988; Hanan and Diamond, 1989; Konno, in press) and the 1990 to 1993 NMFS observer program (Lennert *et al.*, 1994; Perkins *et al.*, 1992; Julian, 1993; 1994). Missing data indicate no available estimates.

	Observation period								
From	4/83	4/84	4/85	4/86	4/87	7/90	1/91	1/92	1/93
To	3/84	3/85	3/86	3/87	3/88	12/90	12/91	12/92	12/93
Effort									
Est. no. net pulls	26,210	37,155	39,104	39,497	29,623	8,070	22,300	16,900	16,300
Effort in days	-	-	-	-	-	3,041	7,089	5,468	5,380
No. observed net pulls	962	1,723	1,499	2,107	978	406	2,231	2,155	2,641
% observed net pulls	3.7%	4.6%	3.8%	5.3%	3.3%	5.0%	10.0%	12.8%	16.2%
Observed marine mammal mortality									
Harbor porpoise	14	19	33	16	13	4	5	6	2
Common dolphin	-	-	-	-	-	0	0	2	0
California sea lion	76	69	84	90	174	67	149	340	239
Harbor seal	31	66	148	103	156	30	43	93	71
Northern elephant seal	-	-	-	-	-	13	3	7	11
Southern sea otters	-	-	-	-	-	3	0	0	0
Estimated marine mammal mortality									
Harbor porpoise	303	226	227	197	34	44	38	44	12
Common dolphin	-	-	-	-	-	0	0	17	0
California sea lion	3,427	2,244	2,207	4,288	2,722	847	1,858	3,255	1,984
Harbor seal	834	1,138	1,886	2,028	903	392	559	1,136	480
Northern elephant seal	-	-	-	-	-	144	26	51	71
Southern sea otters	-	-	-	-	-	33	0	0	0

(C) Washington gillnet fisheries for salmon

Gillnets are used to catch salmon in Washington state by both Native Americans and non-native commercial fishermen. By treaty, half the surplus salmon production is allocated to Native Americans. Set nets are used by the Makah tribe in western Washington (Gearin *et al.*, 1990; 1994). The incidental take of harbor porpoises in this fishery was recognized after unusually large numbers of porpoise were found dead on beaches of the Olympic National Park (Kajimura, 1990). In 1988–89, a cooperative study was initiated between NMFS and the Makah Tribal Fisheries Management Division to study the magnitude of harbor porpoise mortality in this fishery and the size of the affected populations (Kajimura, 1990; Gearin *et al.*, 1990; 1994). Another gillnet fishery for salmon by Native Americans takes place from Semiahmoo Bay, Washington. Incidental mortality of cetaceans has been recorded in this fishery (Baird and Guenther, 1994), but little information is available.

The non-native salmon allocation is divided among sport fishing and commercial fishing. The latter includes trolling, purse seining and gillnetting which have not been covered by observer programs.

Primary ports

The primary ports are Neah Bay, Sekiu and Semiahmoo Bay (Native Americans) and Seattle, Grays Harbor, and Willapa Bay (commercial).

Target species

The target species are chinook salmon (Makah tribe) and all salmon species (non-native commercial).

Area of operation

The area of the Makah fishery is along the northwest coast of Washington state in the Pacific Ocean and in the Strait of Juan de Fuca east to the Sekiu River and including Neah Bay. The non-native commercial fishery is in the Strait of Juan de Fuca and Puget Sound, Columbia River, Grays Harbor and Willapa Bay.

Vessels and crew

The Makah fishing vessels are small, 5–7m skiffs crewed by 1–3 US fishermen (Native Americans only). The current fleet size is 6–10 boats. In the non-native commercial fishery, approximately 600 vessels fish in the Columbia River, Grays Harbor and Willapa Bay, and, although 1,146 vessels were issued gillnet permits to fish in Puget Sound in 1990, the actual number fishing is somewhat less than this. The size of commercial vessels is probably similar to those in Prince Williams Sound, Alaska (see G below) given that many vessels there also fish in Puget Sound (Wynne, unpublished data).

Gear specifications

In the Makah fishery, monofilament and multifilament nylon nets are used with a stretch mesh size of 19–22cm and a maximum length of 183m. Nets are up to 100 meshes deep. In the non-native commercial fishery, nets are 230–550m long (typically 550m), 30–180 meshes deep and have mesh sizes of 13–22cm (net configurations vary with species and area).

Operations

In the Makah fishery, nets are set along the bottom in water depths of 11–18m and are anchored at both ends. Fishermen can fish a maximum of three 183m nets. The fishing season is from 1 May to 15 September with maximum effort in July and August. Nets are usually tended each day, but are typically not picked up or moved. Soak times can exceed 48hrs due to adverse weather. In the non-native fishery, driftnets are used.

Economics and history
In the 1950s, the Makah fishery was conducted primarily in Mukkaw Bay. The effort at that time was about 10 boats with as many as 6 nets per boat and catch rates were up to 75–100 fish per night. The fishery expanded in area in the 1970s.

The non-native fishery has declined consistently since 1974, when the number of gillnet licenses in Puget Sound peaked at approximately 2,000.

Total landings
In the Makah fishery, total landings were 6,404 and 1,690 chinook salmon, respectively for 1988 and 1989. For the non-native fishery in 1991, total landings from Puget Sound were 182,040 chum, 68,702 coho, 15,771 chinook, 174,147 pink and 417,526 sockeye salmon.

Effort data
The estimated effort in the Makah fishery was 2,600 net-days in 1988 and 1,342 net-days in 1989. There are no data for the non-native fishery.

Interactions with cetaceans
The most common cetacean/fishery interaction is with harbor porpoises. Gaskin (1984) reported that in 1972, Ken Balcomb found carcasses of 19 harbor porpoises (many with net marks) on the coast of Washington, possibly killed in a salmon gillnet fishery. An observer program was begun in 1988 to monitor marine mammal bycatch in the Makah fishery. Incidental take included at least 102 harbor porpoises in 1988, 23 in 1989 and 13 in 1990 (Gearin *et al.*, 1994). The take in 1988 was thought to be abnormally high. Studies of body temperature revealed that at least some harbor porpoises entangled during daylight hours. One minke whale was also taken in 1988. Harbor porpoises were used by Native Americans for subsistence purposes. A mandatory observer program is currently monitoring marine mammal mortality in the Makah fishery, but not in the non-native commercial fishery.

Less is known about cetacean mortality in the non-native gillnet fishery. Everitt *et al.* (1979) note Dall's porpoise captures in both salmon gillnets and seines in the San Juan Islands. Flaherty and Stark (1982) note one incident of harbor porpoise mortality in a gillnet in southern Puget Sound. Osborne *et al.* (1988) also note that both harbor and Dall's porpoises are killed in salmon gillnets in Puget Sound and the San Juan Islands. Ken Balcomb (pers. comm.) has noted an increase in harbor porpoise strandings coincident with the occurrence of salmon gillnet vessels in the San Juan Islands.

The population of harbor porpoises in Washington was estimated as 9,800 (SE 4,300) in 1984 (Barlow, 1988). Subsequent surveys of northern Washington (in the immediate area of the fishery) indicated a local abundance of only 634 harbor porpoises (Calambokidis *et al.*, 1993). Harbor porpoise stock structure in this area is not well understood.

Pinniped bycatches and other information
Fishermen reported that 24 harbor seals and 1 sea otter were also taken in 1989.

Discussion
The impact of fishery mortality on harbor porpoises in this area is likely to depend strongly on porpoise stock structure. If porpoise movement between the fishing areas and the southwestern coast of Washington is limited, incidental fishing mortality could severely deplete local harbor porpoise populations. There is a need for more information on porpoise stock structure and movement patterns and for updated estimates of porpoise abundance in surrounding areas.

(D) British Columbia driftnet fishery for salmon
The salmon driftnet fishery in British Columbia has been in operation for most of the century. Fishing occurs primarily in inshore waters. Levels of take of small cetaceans and one species of large whale have been estimated for this fishery by Stacey *et al.* (1990) and Baird *et al.* (In press), respectively. Prior to these recent estimates, evidence of marine mammal bycatch came from opportunistic observations or reports by fisheries officers or fishermen. No formal observation program has been undertaken.

Primary ports
The primary ports are Vancouver and Prince Rupert.

Target species
The primary target species are sockeye, chum, pink, coho and chinook salmon.

Area of operation
Gillnet fishing is permitted in inshore waters of British Columbia, in statistical reporting areas 1–29, which are shoreward of a so called 'surfline'. Regulations may vary between statistical areas.

Vessels and crew
Vessels range from 6–21m in length, with an average of 10.2m for gillnet vessels and 11.6m for gillnet/troll combination vessels. Both bowpicker and sternpicker designs are used. Fishing is controlled by a limited entry system. In 1989 there were 3,230 license holders for gillnet fishing, of which 2,540 held combination gillnet/troll licenses. Most license holders fish every season. Fish are kept in refrigerated seawater or on ice. The crew of 1–5 are Canadian.

Gear specifications
A multifilament nylon net is used with stretched mesh sizes of 10–22cm, with an average mesh of 13cm. Mesh size varies depending on the fish species and local regulations. Except for Area 20, regulations allow panel lengths between 135–375m and net depths of 60 meshes. In Area 20, the maximum size is 550m length and 90 meshes depth. Each vessel fishes only one panel. Floats are approximately 9 x 14cm and are tied to a mixed nylon and polypropylene cork line. Typically the cork line is tied every 1.2m to a 'weed' line, from which the net is hung. The weed line is 6mm polypropylene. The net is tied approximately every 20cm to the weed line. A lead line attached to the bottom of the net is usually about 55m longer than the net and consists of a lead core with a nylon cover, weighing approximately 1 pound per fathom (about 0.25kg per metre). During daylight all nets must be marked at both ends with a plain orange or colored iridescent buoy not less than 125cm in circumference. From one hour after sunset to one hour before sunrise, net ends must be marked with a lantern giving a steady white light. No flashing lights may be used.

Operations
Fishermen remain in attendance of their nets at all times. Fishing occurs from early June to mid September and from early October to the end of November. During this time, only a limited number of fishing openings will take place. Each opening is typically for a specific run of a specific species of salmon, and the length of an opening depends on the catch of that species and on the incidental catch of species which require protection, such as chinook salmon. Openings range from 12hrs to 4 days in length. Nets are typically set in waters less than 183m in depth and are suspended from the surface. Nets are not anchored; set nets are prohibited by regulations. Gillnets cannot be used to enclose an area. Fishing usually occurs from dusk to dawn and soak times vary between 1.5–5.0hrs. Fishing times depend on the length of the opening, the time of day that the opening begins and tidal conditions.

Economics and history
Salmon is used for both domestic consumption and export. Most of the catch is canned. Pearse (1982) reviews the history and management of fisheries on the BC coast. The fishery is presently a limited-entry fishery with a relatively constant number of permits. Between 1979–1988, gillnet catches of salmon have fluctuated between 21,100 and 26,130 tonnes. Total payments to fishermen have also fluctuated but have generally increased. Between 1951 and 1988, the percentage of the total salmon catch taken by gillnets has decreased relative to other gear types, from about 40% in the 1950s to about 25% in the 1980s. Over the same time, total salmon landings have remained relatively constant. It is not known if total gillnet effort has also decreased.

Total landings
In 1988, 19,204 tonnes of salmon were taken by gillnets, including 8,966 tonnes of chum and 7,591 tonnes of sockeye salmon. The salmon fishery (including all gear types) is Canada's most valuable fishery, with an annual landed catch value in excess of $275 million in recent years.

Effort data
In 1988, the fishing effort totalled 54,770 net-days. This effort was concentrated in the periods 26 June to 30 July (25,035 days fished), 31 July to 27 August (14,028 days fished) and 25 September to 29 October (10,738 days fished).

Interactions with cetaceans
Species known to have been caught in or involved in collisions with salmon gillnet gear include harbor porpoises, Dall's porpoises, Pacific white-sided dolphins, killer whales, gray whales and humpback whales (Pike and MacAskie, 1969; Goodman, 1984; Jefferson, 1987; Langelier *et al.*, 1990; M. Bigg, unpublished data; R. Baird, unpublished data). Stacey *et al.* (1990) estimated that at least 55 harbor porpoises, Dall's porpoises and Pacific white-sided dolphins collide with gillnets each year and that between 53–62% die as a result. However, numerous biases in the methods used to derive these estimates suggest that these estimates under-represent actual numbers of gear collisions and thus total mortality. Baird *et al.* (In press) estimate that 11 gray whales collide with gillnet gear each year and that 6.3% are killed. There are only two records of humpback whale entanglement in gillnets and the fate of those animals is not known. Cetaceans are generally discarded, but in responding to a questionnaire survey (Stacey *et al.*, 1990), one fisherman reported consuming caught porpoises.

Virtually nothing is known about the local populations of the two species which appear to be most frequently taken (harbor and Dall's porpoise) and thus evaluating fishery impacts is impossible. Cowan (1988) noted that harbor porpoise populations in British Columbia could be decreasing due to mortality in gillnet fisheries. Gaskin (1992) recommended to the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) that the British Columbia population of harbor porpoises be listed as 'threatened', but the Committee did not so designate the population due to insufficient information. Populations are increasing for gray whales (Buckland and Breiwick, In press) and killer whales (Olesiuk *et al.*, 1990), so takes presumably are having a small impact.

Discussion
Research into bycatches in British Columbia has been limited but has shown the presence of some levels of incidental mortality. More research is needed to determine species taken, mortality level, areas of high catches and other details.

The salmon fishery is regulated by statistical area (and sub-areas), and the length and time of openings are also regulated. Since the abundance or density of small cetaceans probably varies along the coast, it may be possible to reduce bycatches in specific areas by closures or restriction of specific localized salmon fisheries. However, for such regulations to be feasible, additional detailed information on population size and movements is necessary.

(E) Western Canadian driftnet fishery for neon flying squid
This experimental fishery (now discontinued) was undertaken to evaluate the economic viability of using large-scale drift gillnets to catch flying squid off British Columbia (BC) and in adjacent international waters. Although an early report did not refer to marine mammal mortality (Bernard, 1981), later reports confirmed that marine mammals were caught each year (Jamieson and Heritage, 1987). The study concluded that commercially exploitable densities of flying squid did exist off BC, but that bycatch problems would probably have to be resolved before a commercial fishery could begin (Jamieson and Heritage, 1988).

Target species
The experimental fishery only targeted neon flying squid.

Area of operation
Fishing generally took place in Canadian and international waters from northern BC (approximately 54°N) to southern Oregon (approximately 42°N), between 50–300 miles off the BC coast and 200–300 miles off the US coast.

Vessels and crew
Five vessels were used, ranging from 22–55m: one Canadian tuna vessel, two Japanese squid vessels and two Canadian freezer blackcod trap vessels. Two vessels fished in 1980 and 1983, one in 1985, three in 1986, and two in 1987. Crews ranged from 7–27 and were Canadian and Japanese.

Gear specifications
Eight-gauge nylon monofilament nets were used with stretched mesh sizes of 11–12cm. On the Japanese vessels, panels were 48–50m long and 8.5m deep. On one of the

Canadian vessels, two panel lengths were used: 100 and 200m, both being 7.2m deep. The average net length fished by the Japanese vessels was about 45km and net lengths for the three Canadian vessels were about 19, 12 and 4km. Float information is only available for one of the Japanese vessels. It used 220g floats at approximately 1m intervals along a 5mm polypropylene float line. Radio buoys were set at the ends of each group of panels.

Operations
Fishing occurred from mid June through early September. The Japanese vessels remained in the fishing area the entire period, whereas the Canadian vessels left periodically to unload catches. Fishing occurred outside the 1,830m depth contour to minimize bycatch of salmon. On the Japanese vessels, 220–250 panels were set in calm weather and 110–125 panels in rough weather. Nets were suspended from the surface and were free to drift. Nets were pulled at first light after soak times of approximately 12hrs. The Japanese vessels could retrieve an average of 3.8km of net per hour. The Japanese vessels averaged 232kg of squid per km of net per night.

Economics and history
The fishery was concluded to be economically feasible but was discontinued largely due to the high levels of marine mammal bycatch found in the small experimental fishery.

Total landings
Squid landings in 1987 were greater than 1,500 tonnes (Jamieson and Heritage, 1988).

Effort data
Effort was reported as 1,474, 2,475, 4,307 and 4,417km net-nights in 1983, 1985, 1986 and 1987, respectively (Jamieson and Heritage, 1988).

Interactions with cetaceans
Species taken included Dall's porpoise, northern right-whale dolphin, Pacific white-sided dolphin, killer whale, short-finned pilot whale, an unidentified *Stenella* sp., and Cuvier's beaked whale. [Although Jamieson and Heritage (1988) note a single harbor porpoise taken, the great depth at which this would have occurred and the tentative nature of the identification given by the original observer (field notes provided by G.D. Heritage) lead us to conclude that it was not a harbor porpoise.] Cetaceans were not feeding on fish or squid in the net, but rather appeared to blunder into the net without detecting its presence (Jamieson and Heritage, 1988). From observer field notes provided by D. Heritage (Department of Fisheries and Oceans, Nanaimo, BC), animals were caught in all areas of the net. Those close to the cork line were occasionally alive and were released. Twenty individuals were released alive; 145 were caught and killed (Table 4). The mortality rate varied greatly with year and vessel, with a range of 0.03 to 0.001 cetaceans per km net-night and with a mean of 0.012 per km net-night. Typically, dead cetaceans would tear the net and fall out during net retrieval. Dead cetaceans were not utilized. Details on animals caught and released alive are presented by Baird and Stacey (1991; 1993) and Stacey and Baird (1991).

Jamieson and Heritage (1988) noted that one of the eight net groups operated by one of the Japanese vessels during 1987 had 20 consecutive tans (1km of net) with 2 meshes of hollow-core 3-thread filament woven into the 80-mesh deep net at meshes 39 and 40. The rationale was that air trapped inside the thread might improve detection of the net by marine mammals by presenting a stronger acoustic target. This net group was fished on 17 nights, but no information was presented on catches in that section of the net.

Table 4

Cetacean mortality in the British Columbia experimental squid fishery (from Jamieson and Heritage, 1988). Animals caught and released are not included.

Species	1983	1985	1986	1987
Dall's porpoise	3	1	33	58
Short-finned pilot whale	1	-	5	3
Pacific white-sided dolphin	-	1	3	16
Harbor porpoise	2	-	-	1
Northern right-whale dolphin	-	-	4	9
Killer whale	-	-	2	-
Cuvier's beaked whale	-	-	1	-
Stenella sp.	-	-	-	1
Unidentified	-	-	2	-
Total	6	2	50	87

Pinniped bycatches and other information
Two northern fur seals and one Steller sea lion were recorded killed in this fishery.

Discussion
If this fishery is ever started again, it is clear that the potential is great for significant impact on marine mammal populations. Any additional fishing of this type should be carefully monitored. Before this should be allowed, more information is needed on the size and status of the affected populations.

(F) Yakutat and southeastern Alaska gillnet fisheries for salmon
Gillnet fishing for salmon is allowed only with set nets in the Yakutat district and only with driftnets in the southeastern Alaska district.

Primary ports
The primary ports are Sitka, Ketchikan, Petersburg, Haines, Juneau and Yakutat.

Target species
All five species of Pacific salmon are targetted, with primarily sockeye and chum in southeastern Alaska and sockeye and coho in Yakutat.

Area of operation
Operations are carried out in inshore waters of southeastern Alaska and between Cape Yakataga and Cape Fairweather.

Vessels and crew
In southeastern Alaska, vessels are typically 7–11m with a crew of 1–3 US fishermen. In Yakutat, small skiffs are run by 1–2 US fishermen, but some nets are also operated from shore without use of boats.

Gear specifications
For southeastern Alaska driftnets, the maximum net length varies from district to district, but is between 388 to 550m. Maximum depth is 60 meshes for nets with less than 20cm mesh and 40 meshes for nets with 20cm or larger mesh. For Yakutat set nets, the maximum length varies

from 27m per net to 137m in aggregate for three nets. Maximum net depth is 45 meshes for nets with mesh size <20cm and 35 meshes for sizes >20cm.

Operations
Only driftnets are allowed in southeastern Alaska and only set nets are allowed in the Yakutat district. One net is fished by each vessel and the vessel must remain in attendance of the net. The drift gillnet season typically starts on the third Sunday in June and closes in late September or early October. Weekly fishing hours are set by emergency order, but typically last from Sunday through Wednesday and Sunday through Tuesday in northern and southern areas, respectively. Native Americans manage their own fisheries within 92 miles of the Annette Island Indian Reservation, where they use gillnets and purse seines. In the Yakutat area, seasons vary by district, but typically run in June through September, subject to emergency closures.

Economics and history
The value of landings varies annually and by species. Total earnings, in thousands of dollars, in 1987 and 1988 are given in Table 5.

Table 5
Total earnings ('000s$) in the Yakutat and southeastern Alaska fisheries for salmon, 1987 and 1988.

	Southeastern Alaska		Yakutat	
Species	1987	1988	1987	1988
Chinook	144	259	54	35
Sockeye	9,718	13,440	3,079	3,158
Coho	2,168	3,895	1,378	4,916
Pink	3,013	3,527	15	274
Chum	6,072	14,269	61	317
Total	$21,115	$35,390	$4,586	$8,701

Total landings
Yakutat landings were approximately 254,000 sockeye, 122,000 coho, 14,000 chum, 13,000 pink, and 1,750 chinook salmon for 1987 and 158,000 sockeye, 188,000 coho, 27,000 chum, 109,000 pink, and 870 chinook salmon for 1988.

Effort data
As in other Alaska salmon fisheries, effort is controlled by limited entry and by monitoring salmon escapement. There are 164 permanent permits in the Yakutat set net fishery and 468 permanent permits in the southeastern Alaska driftnet fishery. In Yakutat, the total number of permits fished in 1987 and 1988 were 154 and 159, respectively. For southeastern Alaska, the totals were 466 and 471, respectively.

Interactions with cetaceans
There have been no observer programs or other directed studies of marine mammal entanglement in gillnet fisheries in this part of Alaska. The NMFS Alaska Regional office in Juneau collects reports regarding marine mammal entanglement in gillnets and other fishing gear (NMFS, Alaska Region and Northwest Region, unpublished data). Since 1984, there have been 19 reports of humpback whale entanglement, of which 17 were in fishing gear (8 in gillnets, 4 in longlines or buoy lines, and 5 in unidentified gear). Eleven of these whales were freed by fishermen or volunteers, 1 freed itself, 1 died in a gillnet and 4 reports were unconfirmed with unknown outcome. The other two non-fishing entanglements were with abandoned logging gear and a boat anchor line. Six of the entanglements (including one death) occurred between 22 June and 22 July, 1987 in Upper Lynn Canal, south of Haines, Alaska. This anomalous situation probably resulted from an exceptionally dense aggregation of whale forage, probably sandlance, in an area of high gillnet effort. There were no reports of whale entanglement in Upper Lynn Canal in other years. In addition to humpback whales, one gray whale died in a stranding or entanglement incident at the mouth of the East Alsek River. The whale apparently followed schools of capelin over a sand bar at an extreme high tide and became entangled in set gillnets inside the sandbar. It was not clear whether the whale could have avoided stranding if it had not become entangled. There are anecdotal reports from individual fishermen of porpoise entanglements, probably both harbor and Dall's porpoises. Most may be released with little or no harm, but some may be killed. The opportunistic reports probably underestimate the total level of marine mammal entanglement.

In logbook reports submitted to NMFS for 1990 through 1992, fishermen reported 13 Dall's porpoise, 8 harbor porpoise, 1 Pacific white-sided dolphin and 8 unidentified cetaceans killed in the southeast Alaska driftnet fishery and no cetaceans in the Yakutat set net fishery (NMFS, unpublished data).

Pinniped bycatches and other information
Fishermen have reported one harbor seal, one sea otter and one northern elephant seal as being taken in gillnet fisheries in southeastern Alaska (NMFS, Alaska Region and Northwest Region, unpublished data). Previously, in response to harbor seal depredation of the salmon gillnet catch near the Stikine and Taku Rivers in southeastern Alaska during the 1940s and 1950s, resource managers hired seal hunters and levied bounties on seals (Imler and Sarber, 1947).

In 1990–92 NMFS logbooks, fishermen in southeastern Alaska reported 2 northern sea lions, 1 unidentified sea lion and 6 harbor seals killed in drift gillnets, and Yakutat fishermen reported, 12 harbor seals and 18 spotted seals killed in set gillnets (NMFS, unpublished data).

Discussion
There is a need for more information on cetacean entanglement in this fishery. There is no plan for an observer program to monitor marine mammal interactions in this fishery.

(G) Prince William Sound driftnet and setnet fisheries for salmon
The driftnet fishery includes areas from Prince William Sound to the Copper River Delta, Alaska. Marine mammal interactions with salmon driftnet fishermen on the Copper River Delta have existed for decades and have been relatively well documented. The setnet fishery occurs in western Prince William Sound.

Primary ports
The primary ports are Cordova, Whittier and Valdez, AK.

Target species
The target species are sockeye, chinook, chum, pink and coho salmon.

Area of operation
Operations take place in northwest Prince William Sound and the Copper/Bering River Delta.

Vessels and crew
Driftnet vessels are usually 7–11m long and made of fiberglass or aluminum. Both bowpicker and sternpicker designs are used. The crew is usually 1–2 US fishermen. Set nets are typically tended by small, open skiffs.

Gear specifications
In the driftnet fishery, multifilament nylon nets are used with stretched mesh sizes of 12–18cm. Vessels fish only one net panel which is a maximum of 275m long and is typically 90–240 meshes deep (8–27m). Late in the season when the sun is lower, beacons are required to mark the ends of the net during night sets. Driftnets are hauled with a net reel. Set nets are typically hauled and tended by hand.

Operations
Durations of fishing trips are dependent on Alaska Department of Fish and Game (ADF&G) openings (allowable fishing periods); openings are variable depending on the time of year and run strength, but may generally be from 12hrs to 7 days long. Typically there are less than 30 openings per season. Driftnets are fished at the surface in waters less than 366m (Prince William Sound) or less than 128m (Copper River Delta). Vessels are not allowed to anchor and must remain in attendance of their net. Nets may be set throughout the day, but fishing may be limited by tides in some areas. Soak times are typically 15 minutes to 5hrs. It may take 15–90 minutes to haul the net, depending on the catch. The catch is typically 0–1,000 fish per set. Set nets are hung from the surface, anchored at one end and set roughly perpendicular to shore.

Economics and history
Prices for landings vary annually and by species. In 1990, the average prices were $5.28/kg for sockeye salmon, $0.66/kg for pink salmon and 2.20/kg for coho salmon. The total ex-vessel value for the driftnet catch was $35.5 million in 1988. Fish are processed locally as fresh, frozen and canned salmon (and roe) and are shipped to domestic and foreign markets. Salmon originally released from hatcheries constitute 50–70% of the fish harvested in recent years.

Total landings
Combined landings for Prince William Sound and the Copper River Delta are given in Table 6.

Table 6

Combined landings (number of fish caught) for Prince William Sound and the Copper River Delta, 1988 and 1989.

Species	1988	1989
Chinook salmon	31,366	31,336
Sockeye salmon	724,619	1,171,335
Coho salmon	421,203	276,456
Pink salmon	1,562,221	705,431
Chum salmon	562,200	199,754
Total	3,304,609	2,384,312

Effort data
Effort in Alaskan commercial salmon fisheries is controlled by 'limited entry'. There are 550 permit holders for the Prince William Sound/Copper River driftnet fishery and 30 permit holders for the set net fishery. Of the driftnet permit holders, 519 reported landings in 1987 and 525 reported landings in 1988.

Interactions with cetaceans
Cetacean interactions in this fishery involve harbor porpoises, Dall's porpoises, killer whales and humpback whales. The larger cetaceans reportedly swim through the nets. There have been no documented deaths of large cetaceans. Porpoises get entangled in the net, but some 50% of harbor porpoises and 33% of Dall's porpoises are reportedly released alive (Matkin and Fay, 1980; Wynne, 1990; Wynne *et al.*, 1991; 1992). Harbor porpoises are generally not badly entangled and are easily rolled out of the net. Dall's porpoises are more severely entangled and often have to be cut from the gear. Porpoises are generally not brought aboard due to the limited size of the vessels. One entangled humpback whale calf was released when two vessels applied tension at each end of the net.

Twelve of 31 harbor porpoise carcasses examined from the Copper River Delta between 1988 and 1993 bore net marks indicating that they had been entangled (Wynne, 1990; Wynne *et al.*, 1991; 1992). The cause of death for the remaining specimens could not be determined. Matkin and Fay (1980) estimated that 58 harbor porpoises and 31 Dall's porpoises were killed in the salmon driftnet fishery in 1978. Based on dockside interviews in 1988, Wynne found no harbor porpoises taken in 67 trips, a rate that is not significantly different from that obtained by Matkin and Fay in 1978 (4 taken in 179 trips) ($p > 0.1$). Total marine mammal mortality was not estimated in the 1988 study due to clumped distributions and small sample sizes. A manditory observer program monitored marine mammal mortality in the Prince William Sound fisheries in 1990 (setnet and driftnet) and in 1991 (driftnet only). No marine mammal entanglements were observed during more than 300 hours of setnet monitoring. In 1990, 2 harbor porpoise entanglements (one dead, one released alive) were documented in 3,166 observed driftnet sets. The extrapolated mortality estimate was 8 harbor porpoise for the observed portion of the 1990 season (Wynne *et al.*, 1991). In 1991, 7 porpoise entanglements (4 dead, 3 released alive) were documented in 5,875 observed sets. Extrapolated across the driftnet fishery, an estimated 43 harbor porpoise died incidentally in this fishery in 1991 (Wynne *et al.*, 1992). In 1990–92 logbooks, fishermen also reported the catch of Dall's porpoise, white-sided dolphin and common dolphin in this fishery (NMFS, unpublished data).

Both harbor and Dall's porpoise are common in this area, but the impact of fishery interactions on their populations is unknown. In 1993, NMFS conducted aerial surveys to determine their abundance in this area, but estimates are not yet available.

Pinniped bycatches and other information
Matkin and Fay (1980) estimated total pinniped mortality as 516 harbor seals and 333 Steller sea lions (including both incidental and intentional take). Ten years later, Wynne (1990) found that the rate of intentional pinniped take was much reduced. Data from 1990 and 1991 observer programs indicate that pinniped interactions are frequent with driftnets on the Copper River Delta but are rarely

lethal. Lethal entanglements of 3 harbor seals and 1 Steller sea lion were recorded during 3,166 sets observed in 1991 for the Prince William Sound/Copper River Delta areas. Mean estimates of total pinniped mortality were 36 in 1990 and 27 in 1991 (Wynne *et al.*, 1991; 1992). In 1990–92 logbooks, fishermen also reported lethal entanglements of northern fur seals (2) and a sea otter.

Discussion
Entanglement and driftnet related cetacean mortality in this fishery appears limited to smaller species, primarily harbor porpoises. Although entanglement appears to be infrequent and is not necessarily fatal, assessment of its impact requires a better understanding of the populations' abundance, status and trends.

(H) Cook Inlet driftnet and set net fishery for salmon
Cook Inlet supports a large driftnet fishery and a set net fishery, both for salmon. Little is known about marine mammal entanglement in these fisheries.

Primary ports
The primary ports are Kenai, Kasilof, Homer and Ninilchik, Alaska.

Target species
The main target species is sockeye salmon (and to a lesser degree the other four species of Pacific salmon).

Area of operation
Driftnets are used in the central district of upper Cook Inlet, from the latitude of Anchor Point northward to the latitude of Boulder Point. Set nets are used along most of the shoreline of Cook Inlet.

Vessels and crew
Driftnet vessels range in length from 7–22m. Smaller vessels are typically made of aluminum and larger vessels of wood or steel. Crews range from 1 to 5 US citizens. Set net vessels are primarily small skiffs operated by 1–2 US fishermen.

Gear specifications
For driftnets, the maximum net size is 275m long by 45 meshes deep. The maximum mesh size is 15cm and typical size is 13cm. For set nets, the maximum length is 64m per net and with a maximum of 192m in aggregate. The maximum mesh size and net depth is the same as for driftnets in this area.

Operations
Only one driftnet is fished by each vessel and the vessel must remain in attendance of the net. The fishing season is from 25 June to September, but most fishing stops in mid-August. Typically there are only two 12-hour openings each week when fishing is allowed. The length and frequency of these openings can vary with the strength of the salmon run.

Economics and history
The value of landings varies annually and by species. Total earnings, in thousands of dollars, in 1987 and 1988 are given in Table 7.

Total landings
A total of 2,300,000 sockeye salmon was landed in 1990.

Table 7
Total earnings ('000s$) in the Cook Inlet driftnet and setnet fishery for salmon, 1987 and 1988.

	Drift gillnets		Set gillnets	
Species	1987	1988	1987	1988
Chinook	192	124	1,359	1,326
Sockeye	59,962	71,004	38,852	44,390
Coho	1,001	2,645	1,288	2,844
Pink	32	406	64	572
Chum	584	3,926	381	804
Total	$61,772	$78,103	$41,944	$49,936

Effort data
As in other Alaska salmon fisheries, effort is controlled by limited entry and by careful monitoring of salmon escapement. There are 560 permanent permits in the Cook Inlet driftnet fishery and 743 permanent permits in the set net fishery.

Interactions with cetaceans
There have been no studies of marine mammal entanglement in gillnet fisheries in Cook Inlet. White whales and harbor porpoises have been entangled in drift and set gillnets (NMFS, Alaska Region, unpublished data). In logbooks, fishermen reported 1 Dall's porpoise killed in gear in 1990 and none in 1991 (NMFS, unpublished data). The levels of mortality, release or overall take are not known.

Pinniped bycatches and other information
Earlier, pinniped conflicts led to bounties in the 1950s and an initial quantification of numbers of salmon damaged by pinnipeds (Imler and Sarber, 1947). Recently, incidental takes of harbor seals and Steller sea lions have been reported (NMFS, Alaska and Northwest Region, unpublished data). There were no pinnipeds reported killed in fishery logbooks for 1990 and 1991 (NMFS, unpublished data).

Discussion
Clearly there is a need for more information on cetacean entanglement in this fishery. The relatively small, geographically isolated stock of white whales is of particular concern. There is no plan for an observer program to monitor marine mammal interactions with this fishery.

(I) Kodiak, Alaska Peninsula and South Unimak driftnet and set net fisheries for salmon
Salmon gillnet fisheries exist around Kodiak Island (set nets) and along the Alaskan Peninsula (both set nets and driftnets).

Primary ports
The primary ports are Kodiak, King Cove, False Pass, Sand Point and Port Moller, Alaska.

Target species
The main target species is sockeye (and to a lesser degree chum and pink) salmon.

Area of operation
Gillnets are allowed in the region of Kodiak Island and along the northern shoreline of the Alaska Peninsula from the South Unimak area to Ugashik Bay. The South Unimak fishing zone is a sub-set of the Alaska Peninsula and includes coastal areas within 10 miles of Cape Lutke and along both sides of the Ikatan Peninsula, from Cape Pankof to Cape Lazaref.

Vessels and crew
Driftnet vessels are typically 9–14m in length and have crews of 3 US fishermen. Set net vessels are primarily small skiffs with 1–2 US fishermen.

Gear specifications
Drift gillnets are less than 366m in length and must have a stretched mesh size greater than 13cm. Set nets have a maximum length of 183m with an aggregate length of 275m (Kodiak area) and 92 to 366m (along different regions of the Alaska Peninsula).

Operations
Only set nets are allowed in the Kodiak region, only driftnets in the South Unimak area, and both set and driftnets along the Alaska Peninsula. The fishing season is open from early June to late October (Kodiak) or to September (Alaska Peninsula). The South Unimak fishery is limited to June and July. Fishing is subject to openings and closings by emergency order.

Economics and history
Value of landings varies annually and by species. No information on total landings is available. Total earnings, in thousands of dollars, in 1987 and 1988 are given in Table 8.

Table 8

Total earnings ('000s$) in the Kodiak, Alaska Peninsula and South Unimak driftnet and setnet fisheries for salmon, 1987 and 1988.

	Kodiak set gillnet	
Species	1987	1988
Chinook salmon	4	29
Sockeye salmon	5,638	12,428
Coho salmon	190	415
Pink salmon	914	6,678
Chum salmon	376	1,752
Total	$7,121	$21,303

	Alaska Peninsula (including South Unimak)			
	Drift gillnets		Set gillnets	
	1987	1988	1987	1988
Chinook	194	173	87	114
Sockeye	13,694	20,939	6,118	7,194
Coho	597	1,304	648	1,315
Pink	8	489	90	841
Chum	1,145	2,958	286	773
Total	$15,637	$25,864	$7,229	$10,238

Effort data
Effort in Alaskan commercial salmon fisheries is controlled by 'limited entry'. There are about 187 permanent permits in the Kodiak area and 158 permits for the Alaska Peninsula area. Anyone with an Alaska Peninsula permit can fish in South Unimak. The number of boats actually fishing in South Unimak may reach 140–150 in June and usually drops to 50 in July. Allowable fishing periods (openings) are variable depending on the time of year and run strength, but may generally be from 12–72hrs long.

Interactions with cetaceans
Previous records of entanglement exist for gray whales and harbor porpoises in the South Unimak or Alaska Peninsula (NMFS, Alaska Region, unpublished data). This fishery had a mandatory observer program in 1990. The extrapolated estimate of cetacean mortality in this driftnet fishery was 28 Dall's porpoises in 1990 (Wynne *et al.*, 1991). In 1990–92 logbooks, fishermen also indicated that harbor porpoises were taken in driftnet and setnet fisheries (NMFS, unpublished data).

Pinniped bycatches and other information
In observed sets in 1990, one Steller sea lion and two northern fur seals were briefly entangled, but each broke free unharmed (Wynne *et al.*, 1991). Fishermen's logbooks also indicate that harbor seals, spotted seals and sea otters were killed in setnet and driftnet fisheries in this area (NMFS, unpublished data).

Discussion
Little is know about marine mammal mortality in these fisheries. Except for the small area in the vicinity of South Unimak, there is no plan for an observer program.

(J) Alaskan trawl fishery for pollock and other groundfish
Although the Alaskan trawl fishery for groundfish does not use passive fishing gear and is therefore outside the intended purview of this report, this huge fishery generates massive quantities of lost and discarded net which then acts as passive fishing gear. Some direct marine mammal mortality occurs in addition to entanglement in discarded gear (Loughlin *et al.*, 1983).

Primary ports
The primary ports are Dutch Harbor, Kodiak and Akutan, Alaska.

Target species
The main target species are pollock (approximately 70% by weight), cod (approximately 10%) and various flatfish.

Area of operation
Operations take place in Bristol Bay and other regions in the Bering Sea, and in the Gulf of Alaska, including Shelikof Strait.

Vessels and crew
Trawling vessels are up to 92m long and are of steel construction. Larger vessels have on-board processing capabilities. Smaller vessels take their catch to factory ships or land it in Alaska. Currently most of the vessels are US owned and operated. The at-sea catcher-processor fleet produces frozen pollock filets. During the spawning season, roe is frozen and sent to Japan. The shore-based catcher vessels produce frozen filets and fish paste for *surimi*.

Gear specifications
Trawl nets have a mouth opening of approximately 92m by 69m.

Operations
Vessels use acoustic methods to find dense schools of pollock. Trawlings is conducted both in mid-water and on the bottom.

Economics and history
Since the 1930s, this fishery has evolved from (1) being primarily a Japanese far-seas fishery, to (2) being an international fishery with vessels from Japan, the former Soviet Union, Korea and Taiwan, to (3) being a US/Japanese joint venture, to (4) an entirely US fishery. It is currently the largest single-species fishery in the world. More than 20,000 residents of Alaska and Washington are employed in catching and processing pollock, and the total annual landings are worth approximately $200 million.

Total landings
The current quota on landings of Alaskan pollock is 2,200,000 tonnes. The actual US landings were 230,000, 590,000 and 1,100,000 tonnes for the years 1987, 1988 and 1989, respectively. These landings were worth $45 million, $95 million and $187 million, respectively. The joint-venture landings during the same time decreased from about 900,000 to 270,000 tonnes. In addition to this catch in the western North Pacific, the catch of pollock in the eastern North Pacific is about 3,000,000 tonnes (Northridge, 1984).

Effort data
Effort has increased substantially since the early 1980s. Total landings (joint-venture and US combined) increased from roughly 45,000 tonnes in 1981 to approximately 1,400,000 tonnes in 1988 and 1989.

Interactions with cetaceans
In the past, marine mammal take in the pollock trawl fishery was monitored only on foreign and joint-venture vessels. Prior to 1985, this included virtually all vessels. Cetaceans that have been observed taken between 1986 and 1988 (NMFS, unpublished data) include Dall's porpoises (20), killer whales (2), Pacific white-sided dolphins (3), harbor porpoises (3) and other unidentified cetaceans (18). There has been no evidence of cetacean entanglement in discarded netting, but it should be considered as a possible additional source of mortality.

Pinniped bycatches and other information
The direct catch of Steller sea lions has been observed in the trawl nets. Steller sea lion populations have been declining and this species is currently listed as threatened under the US Endangered Species Act. The cause of the decline is not known, but possible causes include resource depletion by overfishing, incidental mortality in trawl and gillnets, shooting, disease, predation, or combinations of the above. Of the pinnipeds, only Steller sea lions have been caught in substantial numbers in pollock trawls (Lowry *et al.*, 1989). The number of Steller sea lions caught and killed in groundfish trawls averaged 724 from 1978–81, 1,436 in 1982, 324 in 1983, and 355 in 1984 (Loughlin and Nelson, 1986). Direct catch in trawls has also been observed (NMFS, Alaska Fisheries Science Center) for California sea lions (1), northern fur seals (48), northern elephant seals (3), harbor seals (36), spotted seals (3), ringed seals (17), bearded seals (4) and walrus (76). Entanglement in discarded trawl net fragments may be an important factor in the decline of the Pribilof Islands population of fur seals (Fowler, 1982) and may account for an extra 15–20% mortality of juvenile fur seals (Fowler, 1985). Net fragments have also been seen on Steller sea lions (Loughlin *et al.*, 1986). Simultaneous with the development of the fishery was a precipitous decline in Steller sea lion populations in the Gulf of Alaska and Aleutian Islands, from 140,000 in 1960 to 25,000 in 1989 (Loughlin *et al.*, 1990). The direct Steller sea lion mortality is insufficient to explain the marked population decline; however, the effects of the fishery on sea lion prey abundance has been implicated as a potential cause of the decline.

Discussion
Discarded trawl nets and lines litter the beaches on many sites in the Aleutian Islands, Alaska (Merrell, 1985). Seventy-five beaches were examined on 21 Aleutian Islands in 1988–90 in a study on the impact of plastic debris on wildlife (A. Manville, unpublished data; Manville, 1990). Fishing-related debris was found to be the most prevalent form of plastic on the beaches. Fishing debris on these 75 beaches included 4,283kg of rope, 120kg of driftnet buoys, and 6,053kg of fishing net (95% of the net debris was from trawl nets). Although this beach survey found 3 Steller sea lions entangled in plastic debris, in all cases it was strapping bands and not fishing gear. Given the isolated nature of most of these islands, the large quantity of fishing-related debris found on these beaches and indications of the continued loss and/or discard of fishing-related gear, the potential for marine mammal entanglement in passive fishing debris is great. The danger is probably much greater for pinnipeds than for cetaceans.

US vessels are required to have mandatory observers on a subset of their trips. The observed incidental take in 1989 included 5 Steller sea lions, 1 Dall's porpoise and 1 ringed seal. These estimates have yet not been extrapolated to the entire US fleet. In the same year, the observer coverage on the joint-venture fleet was approximately 95% and the bycatch included 3 Steller sea lions, 1 fur seal and 1 unidentified marine mammal.

(K) Bristol Bay set net and driftnet fisheries for salmon
A large, intensive fishery for salmon occurs in the northeastern part of Bristol Bay.

Primary ports
The primary ports are Dillingham, Egegik and Naknek, Alaska.

Target species
The main target species is sockeye salmon, but coho, pink, chum and chinook salmon are also taken.

Area of operation
Operations take place principally in Nushagak and Kvichak Bays and adjacent coastal waters along the Alaska Peninsula.

Vessels and crew
Set net boats are small skiffs crewed by 1–2 US fishermen. Driftnet boats are limited to a maximum of 10m in length and are crewed by 2–4 US fishermen.

Gear specifications
Multifilament nylon gillnets are used with maximum stretch mesh of 11 to 17cm (depending on season). Maximum net length is 183m for set nets and 275m for driftnets. Maximum depth is limited to 29 meshes. Marker floats are required on the free end of the net.

Operations
Set nets are laid perpendicular to shore and are anchored at the seaward end. Some nets are set slightly offshore (<183m) and anchored at both ends. Driftnets must remain attached to the boat on one end with a buoy on the other, free end. All nets float at the surface. Soak times and durations of fishing periods are dependent on fishing conditions and current regulations.

Economics and history
This area has the largest run of sockeye salmon in Alaska and the fishery is consequently large. Most of the fish are frozen, but some are canned or sold fresh. Chinook salmon are important earlier in the year. Fish are sold to both domestic and foreign markets. Value of landings varies annually and by species. Total earnings, in thousands of dollars, in 1987 and 1988 are given in Table 9.

Table 9

Total earnings ('000s$) in the Bristol Bay setnet and driftnet fisheries for salmon, 1987 and 1988.

	Drift gillnets		Set gillnets	
Species	1987	1988	1987	1988
Chinook	1,402	699	372	237
Sockeye	115,696	168,098	18,015	24,920
Coho	134	1,101	193	1,041
Pink	-	782	-	424
Chum	2,643	2,340	332	387
Total	$119,875	$172,991	$18,912	$27,009

Total landings
Combined landings for set and driftnet fisheries were 16,048,000 sockeye, 69,000 coho, 1,510,000 chum and 77,000 chinook salmon for 1987; 14,010,000 sockeye, 187,000 coho, 1,475,000 chum, 922,000 pink and 45,000 chinook salmon for 1988. Total landings in 1989 were 80,557 tonnes for all salmon species.

Effort data
Effort in Alaskan commercial salmon fisheries is controlled by 'limited entry'. There are 943 permanent permit holders for the Bristol Bay set net fishery and 1,746 permanent permit holders for the Bristol Bay driftnet fishery. Allowable fishing periods (openings) are variable depending on the time of year and run strength, but may generally range from 12hrs to 7 days long. Fisheries are managed based on escapement goals, so after the desired escapement is achieved the fishery may be open continuously.

Interactions with cetaceans
A group of about 1,000–1,500 white whales occur in this area, some of which are incidentally caught in gillnets (Brooks, 1954; 1955; Frost *et al.*, 1984). There is no systematic program for measuring the level of take, but studies conducted in 1982–83 suggested that about 10–20 whales per year were killed. Most mortality seems to occur in the chinook salmon fishery which uses larger mesh sizes. Evidence indicates that the white whale population's distribution and abundance was largely the same in 1984 as it was 30 years earlier (Frost *et al.*, 1984). Some take of harbor porpoises is also likely in this fishery.

Non-lethal harassment was used from 1956–72 to displace the white whales which feed on sockeye salmon adults and smolt (Frost *et al.*, 1984). White whales are thought to consume less than 1% of the commercial catch of sockeye salmon and less than 5% of the total smolt production; however, they may consume up to 9% of the commercial catch of other salmon species (Frost *et al.*, 1984).

Fishermen logbooks for 1990–92 indicate that other species are occasionally killed, including the common dolphin, northern right whale dolphin and gray whale.

Pinniped bycatches and other information
Logbook data for 1990–92 show the deaths of 18 harbor seals and 1 spotted seal (NMFS, unpublished data).

Discussion
The group of white whales in Bristol Bay is usually considered to be a separate stock that numbers in excess of 1,000 animals. Although available data suggest that numbers have been stable and that incidental take has not affected the stock, there are suggestions that the level of take has increased since the 1950s. This warrants further study.

(L) Northern Alaska set net fisheries
Harbor porpoises are sometimes taken in gillnets that are set for salmon (and other fish) in Norton Sound, Kotzebue Sound and other areas north of Bristol Bay. Most fisheries interactions are likely to involve pinnipeds, including harbor, spotted, ringed and bearded seals, although there are no published records that describe this interaction.

Primary ports
The primary ports are Nome, Unalakleet, Golovin and Kotzebue, Alaska.

Target species
The main target species are coho, chum and chinook salmon.

Area of operation
Operations are primarily in coastal waters of Norton Sound and Kotzebue Sound.

Vessels and crew
The small skiffs used are crewed by 1–2 US fishermen.

Gear specifications
Mostly multifilament nylon gillnets are used. In Norton Sound, nets have a maximum stretch mesh of 11 or 15cm (depending on season). The maximum length is 183m. In Kotzebue Sound, there are no limitations on mesh size and nets are a maximum of 275m long. There are no restrictions on net depth. Floats are required on the free end of the net.

Operations
Nets are set perpendicular to shore and are anchored at the seaward end. All nets are floating at the surface. Soak times and durations of the fishing season depend on fishing conditions and current regulations.

Economics and history
Subsistence-caught fish are for personal use but may be bartered. Commercially-caught fish are sold to both domestic and foreign markets and may be sold fresh, canned, smoked or frozen. Price and ex-vessel value vary

considerably depending on run strength and market conditions. Value of landings varies annually and by species. Total earnings, in thousands of dollars, in 1987 and 1988 are given in Table 10.

Table 10

Total earnings ('000s$) in the northern Alaska setnet fisheries in 1987 and 1988.

Species	1987	1988
Chinook salmon	6,787	6,880
Sockeye salmon	1,706	2,134
Coho salmon	2,818	7,158
Pink salmon	1	69
Chum salmon	3,382	13,046
Total	$14,694	$29,287

Total landings
In 1989, catches of all salmon species amounted to 337 tonnes in Norton Sound and 989 tonnes in Kotzebue Sound.

Effort data
Effort in Alaskan commercial salmon fisheries is controlled by 'limited entry'. There were 1,952 permanent permit holders in 1987 for the Kuskokwim, Lower Yukon, Norton Sound, and Kotzebue management areas. Fishing periods (openings) are variable depending on the time of year and run strength, but may generally be from 12hrs to 7 days long. Harvests are continually monitored and fishing hours in particular areas are controlled by emergency order to achieve escapement goals.

Interactions with cetaceans
Harbor porpoises are occasionally entangled and drowned. ADF&G has recorded 7 instances during 1981–87 in the area from Nome to Unalakleet and 3 near Kotzebue in 1989–90. One harbor porpoise was even caught in a net set at Barrow (Hall and Bee, 1954). There is no formal program of monitoring and reporting.

Pinniped bycatches and other information
No pinniped bycatch has been reported, but some catch of spotted seals is likely. Any pinnipeds that are taken are likely to be used by Native American fishermen for subsistence purposes.

Discussion
The apparent level of take seems quite large considering the lack of a formal program for monitoring and the opportunistic nature of reports that have been received. Harbor porpoises probably occur in this area only during summer and fall since they would be excluded by sea ice during November-June. It is not known to which population these porpoises might belong.

(M) Driftnet fishery for salmon in eastern Russia
Gaskin (1984) reported that there were no records of harbor porpoise take from Korean waters, from the northern coast of China, or from gillnet operations in far-eastern Russian waters. Little mention was made of fishery/marine mammal interactions in Russian waters by Northridge (1984). Kornev (1994) mentions the entanglement and death of one right whale in a gillnet. There has been no specific research on problems of marine mammal mortality in fisheries of the east coast of the former USSR. Information provided in this review is based on one author's (VNB's) opportunistic observations, on data provided by researchers at the Kamchatka Department of the Pacific Institute of Fisheries and Oceanography, on information provided by inspectors of the Kamchatribvod Protective Service and on reports from the chiefs of Glavribvod and Kamchatribvod of the former USSR Department of Fisheries.

Primary ports
The primary ports are Petropavlovsk-Kamchatsky, Severo-Kurilsk, Vladivostok, Nakhodka, Preobrazhenye, and Hokkaido (Japan)

Target species
The main target species are pink and chum salmon, but all five Pacific species are caught.

Area of operation
Operations take place in the Sea of Okhotsk and the Bering Sea.

Vessels and crew
Driftnet fishing for salmon off eastern Russia is typically by Russian and Japanese fishermen (Kornev, 1994). In 1990, 2 larger (approx. 500 tonnes) and 6 smaller (100–120 tonnes, 40m, crew of 16–18) Japanese vessels participated in this fishery. That same year, 6 larger (800 tonnes, crew of 26) and 3 smaller (<100 tonnes, crew of 10–12) Russian vessels participated. In 1992–94 the number of small Japanese vessels increased to 30–40 per year.

Gear specifications
Nets are constructed of thin-vein, monofilament nylon mesh made in Japan or Taiwan. Panels are 45–50m long by 8–9m deep. Single nets (or 'oders') are made of 50–300 panels. A vessel typically fished 1 or 2 oders in 1990 and 4–7 oders in 1992–94. Each net is marked with lights and radio beacons.

Operations
Drift gillnet fishing for salmon in the eastern economic zone of Russia is conducted under a special research program of the Pacific Institute of Fisheries and Oceanography (PIFO) and, since 1992, as a commercial fishery. Research fishing operations occur from 20–25 July to 10–25 August, although sometimes it is carried into September. Commercial fishing occurs from 20 May to 20–25 July. Fishing takes place in the Sea of Okhotsk and the Bering Sea. Some additional fishing may take place in the northern Sea of Okhotsk and near the northern coast of Sakhalin Island, but information on that region is scarce. Typically nets are set after sunset and are hauled after sunrise or early the next day. Soak times are 9–12hrs.

Economics and history
Russian fishermen in 1990 received 23 rubles, 76 copecks ($30US: official rate, $2–3US: black market rate) per 100kg of cleaned salmon. Fish are cleaned immediately after being caught and are kept refrigerated on the vessel. Fish are sold to foreign and domestic markets.

Total landings
The 1990 landings for Russian vessels in the Bering Sea (in the former USSR economic zone) were 300 tonnes of salmon (approx. 100t pink and 195t chum). Total salmon

landings were down considerably from previous years. Record highs of 2,100 tonnes were recorded in 1988. The 1990 salmon landings from the Sea of Okhotsk and the Bering Sea were approximately 1,500 tonnes. The species composition of the catch varies with natural salmon cycles.

The Japanese driftnet fishery for salmon in the former Soviet economic zone was steady at 4–6,000 tonnes over the years 1987–90 in the region near the Okhotsk and Pacific coasts of the south Kuril Islands. A Soviet-Japanese joint venture firm (Pilenga GODO) fished with Japanese vessels in the Karaginsky Gulf in 1989 and in the Sea of Okhotsk near western Kamchatka in 1990. Total landings were 522 tonnes (and are included in the above 1,500 tonnes).

Effort data
The scientific gillnet fishery for salmon developed in 1986 and reached a peak in 1988. A commercial gillnet fishery in the Russian economic zone increased dramatically in 1992–94 with an agreement between Russia and Japan.

Interactions with cetaceans
In the research fishery, PIFO representatives and vessel captains report Dall's porpoises being caught in the scientific salmon gillnetting (G.E. Karmanov, A. N. Zaochny, M. T. Orlov, and V. A. Shniperov, pers. comm.). Porpoises were caught most frequently near the Kuril Islands, south to 51°N. Fishing in 1990 between 51°-51°30′N and 149°20′-155°50′E, G.E. Karmanov reported (pers. comm.) 8 Dall's porpoises entangled out of 2,295 panels of retrieved net (109.6km), of which 3 were released alive. Captains of two other vessels fishing in approximately the same area reported 20–25 Dall's porpoises killed per fishing season. Porpoises are caught much less frequently in the Karaginsky Gulf (Bering Sea, 58–60°N). In this area in 1990, PIFO natural resource observers saw no porpoises entangled in 5,000 panels of retrieved net. In the 1992–94 commercial fishery, several hundreds of Dall's porpoise were caught each year. Some harbor porpoise and unidentified whales were also caught. Porpoises are typically thrown back into the sea.

One entangled right whale (which died) was discovered on the Pacific side of Cape Lopatka in October 1989. It was caught in a fragment of green 6 x 6cm mesh gillnet with foam plastic floats (Kornev, 1994).

Pinniped bycatches and other information
Northern fur seals, ribbon seals, bearded seals and spotted seals were taken in the 1992–94 commercial fishery (probably less than 10 of each species per year).

Discussion
Fishery inspectors of the Kamchatribvod controlled fishery reported that a rather developed, unpermitted fishery existed in the Sea of Okhotsk and near the Pacific coast of the Kuril Islands prior to 1992. Each year, Russian patrol boats chased off Japanese, Korean and Taiwanese vessels in this area. This unpermitted fishery has been largely replaced by a permitted commercial fishery in 1992. This commercial fishery includes a bycatch observer program which is now providing needed information on marine mammal mortality.

(N) Eastern Russia coastal trap-net fishery for salmon
The vast majority of Russian-caught salmon on the east coast come from nearshore trap nets. These are passive nets that intercept salmon as they travel along the shore to their spawning river and guide the fish into a holding pen. Little information has been published regarding cetacean entanglement in this type of net, but it is considered very rare.

Target species
All five Pacific salmon species are taken.

Area of operation
Operations occur in near shore waters of the Russian Far East.

Gear specification
Trap nets are set with a wing net perpendicular to shore and leading to a trap or pen approximately 200–400m from shore.

Operations
Approximately 6–12 fishermen tend each trap net. Fish are transported to shore-based processing plants in special boats.

Total landings
The vast majority of Pacific salmon caught in Russian waters are caught in trap nets. Average landings in eastern Russian waters from 1987–90 were 131,000 tonnes per year, of which approximately 79,000 tonnes were caught on the Kamchatka peninsula.

Effort data
Annually in June-August, about 50 trap nets are set on the western (Okhotsk) coast of Kamchatka and about 50–80 are set on the eastern coast.

Interactions with cetaceans
Other than one reported narwhal entanglement (I.I. Muroshov, pers. comm.), interactions with cetaceans appear minimal in this fishery.

Pinniped bycatches and other information
Often spotted seals gather in groups of approximately 100 near the traps. Steller sea lions have also been reported. The trap itself is apparently not dangerous to pinnipeds, but fishermen often shoot at them, killing or wounding some.

Discussion
More details regarding the level of pinniped mortality by shooting are clearly needed. However, the available information suggests that this method of fishing appears to be effective at catching salmon without incidental entanglement of marine mammals.

(O) Other fisheries
There are many reports for the eastern North Pacific regarding marine mammals mortality in passive and active fishing gear in fisheries other than those mentioned above. Some of these fisheries are small and others have been discontinued. For completeness, we include all references we were able to find, without providing extensive details. The following list should not be considered complete.

In California, Scammon (1874) first documented the take of harbor porpoises in a beach seine in San Francisco. Although not strictly-speaking entangling gear, many short-finned pilot whales were thought to entangle and die (or were shot) in a market squid purse seine fishery in the California Channel Islands (Miller *et al.*, 1983; Seagers and Henderson, 1985; Heyning *et al.*, 1994).

In Oregon and Washington, significant pinniped mortality has been reported in the Columbia River salmon gillnet fishery (Beach *et al.*, 1985), but cetacean mortality does not seem important there. Scheffer and Slipp (1948) felt that fish nets were responsible for a large number of harbor porpoise deaths each year in Washington state. Harbor porpoises were also killed in trawl gear off Washington State (Leatherwood and Reeves, 1986).

In British Columbia, there are records of cetacean bycatch in several temporary experimental or now-discontinued fisheries. Cowan (1939) reported a minke whale caught in a salmon trap near Sooke, on the southern tip of Vancouver Island. Pike and MacAskie (1969) reported the deaths of three short-finned pilot whales in a gillnet during experimental fishing in international waters off BC and the entanglement of two killer whales in 'fishing gear'. Porpoises are occasionally killed in research fisheries currently being undertaken by the Canadian Department of Fisheries and Oceans; in 1990 a Dall's porpoise was killed in a surface trawl research fishery on salmon smolts and a harbor porpoise was killed in a monofilament sunken set gillnet used in a research fishery for dogfish shark (Baird, unpublished data). In addition to the salmon gillnet fishery described above, five current commercial fisheries are known to take cetaceans in BC. These include salmon seine, salmon troll, bottomfish trawl, shrimp trap, and crab trap fisheries (Le Boeuf, 1974; Baird *et al.*, In press), in the latter two, take involves large whales becoming entangled in lines associated with the traps. In 1990 a gray whale entangled and died in a pen used to hold herring in a herring roe fishery and in 1991 a gray whale was entangled in a herring set gillnet from this fishery (Baird *et al.*, In press).

Frequent marine mammal/fishery encounters have been reported for the salmon purse seine fishery in South Unimak, Alaska (Melteff and Rosenburg, 1984), but more recent investigations by the State indicate that this may no longer be the case (Anon., 1989). Elsewhere in Alaska, four humpback whales were reported to have entangled in buoy lines associated with longline and shrimp pot gear (Sease, pers. data). A killer whale entangled and drowned in a sablefish longline in 1988. Some Steller sea lions also were killed in association with longline fisheries in Alaska, but many probably were killed intentionallly to protect catch and gear. [Currently there is a ban on shooting at or within 100 yards of Steller sea lions throughout their range.] Gray whale mortality due to fisheries ranges from 8.7 to 25.8% of all stranded gray whales from the Alaska Peninsula to Baja California Norte (Heyning and Dahlheim, In press).

Several other passive-type fisheries are found in the waters of eastern Russia. Near western Kamchatka, approximately 10 Japanese vessels fished in 1990 used long-lines for cod, walleye pollack, and flatfish and use traps for crab. Approximately 5–6 Japanese vessels fish for halibut and large perch using bottom-set gillnets in international waters in the middle of the Sea of Okhotsk. In the latter fishery, 20–25cm mesh nets are set at extreme depths of 500–800m. One vessel typically sets 27km of net which is allowed to soak for 2–4 days. No information is available on cetacean mortality in any of these fisheries.

Crustacean trap fisheries occur in most coastal waters including California, Oregon, Washington, British Columbia, Alaska, the western Bering Sea (Russia), and the Sea of Okhotsk. Based on experience elsewhere, trap lines are likely to occasionally entangle and kill some whales. Four of the entangled gray whales mentioned by Heyning and Lewis (1990) were caught in crab or lobster traplines. In British Columbia, there is one record of a humpback whale becoming entangled in lines associated with prawn trap gear (Langelier *et al.*, 1990). In Russia, one gray whale has been seen with a part of a crab trap on its fluke (L.S. Bogoslovskaya, pers. comm.) and a spotted seal has been reported entangled in crab fishing gear.

DISCUSSION

Clearly there is insufficient information on the number of marine mammals that are taken incidentally in passive fishing nets and traps. For many fisheries, there is no information at all. In the case of California gillnet fisheries, for which we have the best data, it is still difficult to evaluate the significance of the observed mortality on the cetacean populations. In all areas, a larger effort is needed both to determine the number of animals killed in fisheries and to evaluate the significance of this mortality to the populations.

Recent US legislation that requires an observer program for certain fisheries is likely to fill many of the gaps in our knowledge about the level of marine mammal mortality in these fisheries. The resulting information will not be complete, however. The US program concentrates on fisheries with a high likelihood of taking marine mammals. Although vessel owners in other fisheries are required to report on levels of fishing effort and marine mammal interactions, there is no validation to ensure accurate reporting. For many fisheries without observer programs, there was no quantitative information on the levels of marine mammal catch. In this situation, a lack of information is perpetuating a continued lack of information. Some, perhaps low level of observation in all fisheries might be appropriate to better estimate the total level of cetacean mortality in US fisheries.

In Canada, the level of knowledge on fishery/marine mammal mortality is poor. The exception is the experimental squid fishery with its 100% observer program. Seldom has bycatch been adequately studied in experimental fisheries and seldom (as it was in this case) is bycatch a factor in deciding against continuing a potentially profitable fishery. In contrast, however, there is little direct information on cetacean mortality in the much larger drift gillnet fishery for salmon in BC. Most of the available information is from questionnaires, which are typically less reliable than direct observation. Some level of direct observation seems necessary in order to validate the level of incidental mortality that was estimated in the questionnaire survey.

In Russia, little information is available on the levels of incidental marine mammal mortality in fisheries. This report was based almost entirely on information for the Sea of Okhotsk and the Bering Sea. More information is needed regarding fisheries near Sakhalin Island and in the Sea of Japan. The largest and economically most important fishery, the trap-net fishery for salmon, appears to have little incidental marine mammal mortality. Driftnet fishing for salmon is, however, increasing rapidly. There is a need to continue studies of marine mammal/fishery interactions in eastern Russia and to expand the program of fishery observers.

It should be recognized that indirect methods of estimating marine mammal mortality in fisheries (including data from stranded animals, from dockside surveys and from questionnaires) are all likely to underestimate total marine mammal mortality. The biases are likely to be

different for each method. Stranding data are likely to underestimate takes from offshore fisheries more than inshore fisheries (Heyning *et al.*, 1994). Problems with questionnaires and dockside surveys are addressed by Lien *et al.* (1994). Indirect methods of estimating bycatch of marine mammals should not be considered as a substitute for direct observation.

Knowing the level of marine mammal mortality in fishing operations is an obvious first step in evaluating the significance of this mortality on the populations of marine mammals. Ideally, one would like to directly measure whether fishery mortality is adversely affecting populations. Data on population trends are rare for most marine mammal species. Populations appear to be increasing for California gray whales, killer whales in British Columbia, California sea lions, northern elephant seals and harbor seals in California, Oregon, Washington and British Columbia. The population of white whales in Bristol Bay appears stable. This type of information gives us some confidence that fisheries are not disadvantageous to these populations. In contrast, there are examples such as harbor seals, northern fur seals and Steller sea lions in Alaska where the populations are declining, but where the reasons for this are not understood and any possible relationship to gillnet entanglement is unclear. Unfortunately, trends in abundance are difficult and expensive to obtain, require long time series and may be difficult to interpret. Although it is anticipated that information on trends in harbor porpoise abundance in California will be available after 4 additional years of study (Forney *et al.*, 1991), this is one of the few cetacean populations for which this is likely. Trends are not always a practical approach to determining the significance of incidental marine mammal mortality in fisheries.

A more basic first step should be to estimate the size of the populations that are being affected by fishery mortality. A comparison between the estimated level of fishery mortality and the population size can quickly indicate whether fishery mortality is likely to be a problem for those populations. Most biologists would agree that incidental mortality rates of less than 1% per year are not likely to have an appreciable impact on a marine mammal population unless that population is suffering from additional factors that result in reduced productivity and/or survival. Similarly, most biologists would agree that incidental mortality rates greater than 4% per year for cetaceans or 10% per year for pinnipeds are not sustainable and could lead to catastrophic population declines. Between these values (1–4% for cetaceans, 1–10% for pinnipeds), there may be considerable difference of opinion as to the likely effect of incidental mortality. Using such a scheme, it is possible to classify fishery mortality on a population as being probably negligible, clearly too high, or potentially too high. Researchers and managers could then take action to reduce mortality where it is obviously too high and to gather adequate data in cases where we are unsure of the potential impact of a fishery on a marine mammal population.

RECOMMENDATIONS

(1) Baseline data on levels of marine mammal mortality for all fisheries based on direct observations and other appropriate methodology should be obtained. Fisheries that are found to have a significant level of marine mammal mortality should continue to be monitored. Countries which allow foreign vessels to fish in their waters may be able to require such an observation program as a condition for obtaining a fishing permit.

(2) Estimates of population size for species that are likely to be adversely affected by fishery mortality should be obtained. For most species, this will include determining stock boundaries, abundance and seasonal distribution. When possible, trends in abundance should be determined.

(3) Alternative fishing strategies that will minimize encounters with marine mammals (e.g. seasonal closures for gillnet fisheries) should be developed.

(4) Consideration should be given to the level of incidental marine mammal mortality when fishery management agencies decide the allocation of fish to various fishing methods. As an example, the use of trap nets for salmon could be allowed in place of using gillnets.

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Appendix 1

SCIENTIFIC AND COMMON NAMES

Marine Mammals	
Bearded seal	*Erignathus barbatus*
Bottlenose dolphin	*Tursiops truncatus*
California sea lion	*Zalophus californianus*
Common dolphin (short-beaked)	*Delphinus delphis*
Common dolphin (long-beaked)	*Delphinus capensis*
Cuvier's beaked whale	*Ziphius cavirostris*
Dall's porpoise	*Phocoenoides dalli*
Elephant seal	*Mirounga angustirostris*
Gray whale	*Eschrichtius robustus*
Harbor porpoise	*Phocoena phocoena*
Harbor seal	*Phoca vitulina*
Hubbs' beaked whale	*Mesoplodon carlhubbsi*
Humpback whale	*Megaptera novaeangliae*
Killer whale	*Orcinus orca*
Mesoplodont beaked whale	*Mesoplodon* spp.
Minke whale	*Balaenoptera acutorostrata*
Narwhal	*Monodon monoceros*
Northern fur seal	*Callorhinus ursinus*
Northern right whale dolphin	*Lissodelphis borealis*
Northern right whale	*Eubalaena glacialis*
Pacific white-sided dolphin	*Lagenorhynchus obliquidens*
Pygmy sperm whale	*Kogia breviceps*
Ringed seal	*Phoca hispida*
Risso's dolphin	*Grampus griseus*
Sea otter	*Enhydra lutris*
Short-finned pilot whale	*Globicephala macrorhynchus*
Sperm whale	*Physeter macrocephalus*
Spotted seal	*Phoca largha*
Stejneger's beaked whale	*Mesoplodon stejnegeri*
Steller or northern sea lion	*Eumetopias jubatus*
Walrus	*Odobenus rosmarus*
White whale	*Delphinapterus leucas*

Fishes	
Angel shark	*Squatina californica*
California halibut	*Paralichthys californicus*
Capelin	*Mallotus villosus*
Mako shark	*Isurus oxyrinchus*
Market squid	*Loligo opulescens*
Neon flying squid	*Ommastrephes bartramii*
Opah	*Lampris regius*
Pacific cod	*Gadus macrocephalus*
Pacific salmon	*Onchorhynchus* spp.
Chinook or king salmon	*O. tshawytscha*
Chum or dog salmon	*O. keta*
Coho or silver salmon	*O. kisutch*
Pink or humpback salmon	*O. gorbuscha*
Sockeye or red salmon	*O. nerka*
Swordfish	*Xiphias gladias*
Thresher shark	*Alopias vulpinus*
Walleye pollock	*Theragra chalcogramma*
White croaker	*Genyonemus lineatus*
White seabass	*Cynoscion nobilis*