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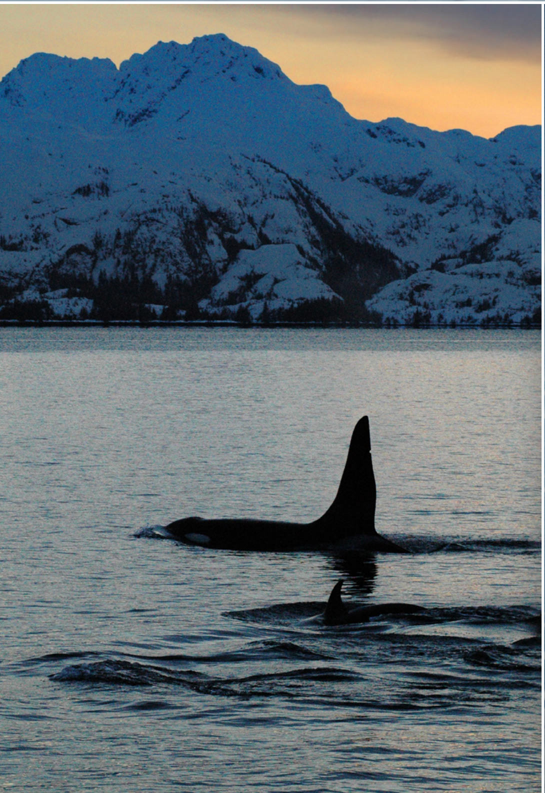
# Killer Whale Entanglements in Alaska

## Summary Report: 1991-2022



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Throughout this technical memorandum, the authors use the term “fishers” to include fishermen, fisherwomen, and everyone fishing commercially or recreationally.

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This report is composed of the input from a broad suite of individuals interested in killer whale conservation, entanglement response, and bycatch reduction. We appreciate their valuable input. Thank you to the fishers, fishing communities, and fishing industry for their continued dedication to minimizing interactions between commercial fisheries and killer whales.

**Cover Photo Credit:**
John Moran
NOAA Fisheries AFSC Auke Bay Lab

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| Abbreviation | Definition |
| --- | --- |
| AFSC | Alaska Fisheries Science Center |
| AK | Alaska |
| AK MMSN | Alaska Marine Mammal Stranding Network |
| AT1 Transient Stock | A genetically unique sect of the killer whale population that lives in the Prince William Sound/Kenai Fjords area |
| BS | Bering Sea |
| BSAI | Bering Sea and Aleutian Islands |
| EFP | Exempted Fishing Permit |
| ESA | Endangered Species Act |
| FR | Federal Register |
| GOA | Gulf of Alaska |
| ID | Identification |
| LWER | Large Whale Entanglement Response |
| MMAP | Marine Mammal Authorization Program |
| MMHSRP | Marine Mammal Health and Stranding Response Program |
| MMPA | Marine Mammal Protection Act |
| NMFS | National Marine Fisheries Service |
| NOAA | National Oceanic and Atmospheric Administration |
| OPR | Office of Protected Resources |
| PBR | Potential Biological Removal |
| PEIS | Programmatic Environmental Impact Statement |
| PLOS One | A scientific journal community |
| SA | Stranding Agreement |
| SAR | Stock Assessment Report |
| SCAK | Southcentral Alaska |
| SEAK | Southeast Alaska |
| UBC | University of British Columbia |
| US | United States |
| USC | United States Code |

# Abstract

This technical memorandum provides a comprehensive summary of 37 killer whale entanglement reports in Alaska from 1991 to 2022. Trawl and longline gear were associated with most reported incidents (n=30). The severity of the entanglements varied, with some whales experiencing no known lasting injury, and others, a majority (n= 25), suffering mortality. There are several factors that correlate with entanglement risk, including gear type, age class, and seasonality. Additionally, we summarize techniques, strategies, and best practices for entanglement responders and review potential bycatch mitigation tactics. This technical memorandum is intended to be used as a resource for researchers, policy makers, and stakeholders working to better understand and lessen the impacts of entangling materials, including fishing gear, on killer whales in Alaska.

# Introduction

Killer whales (*Orcinus orca*) are a ubiquitous predator, and a vital component of the marine ecosystems of Alaska (Young et al. 2023). There are three genetically distinct ecotypes of killer whales that occur in Alaska waters: the Resident ecotype, which primarily feeds on fish, particularly salmon (*Oncorhynchus sp*); the Transient ecotype, which primarily feeds on pinnipeds and cetaceans; and the Offshore ecotype, which feeds primarily on sharks and rays (Bigg 1982, Bigg et al. 1990, Ford, Ellis and Balcomb 2000, Dahlheim et al. 2008). In addition to foraging behavior, these three ecotypes differ in several other aspects of their natural history, including genetics, vocalizations, and social structure (Bigg et al. 1990, Barrett-Lennard 2000, Ford, Ellis and Balcomb 2000, Dahlheim et al. 2008). Under the U.S. Marine Mammal Protection Act (MMPA), killer whale populations are managed as "stocks," which the statute defines as, "a group of marine mammals of the same species or smaller taxa in a common spatial arrangement that interbreed when mature" (16 USC § 1362(11)).

The National Marine Fisheries Service (NMFS) has designated five killer whale stocks in Alaska (Young et al. 2023): three transient killer whale stocks (Eastern North Pacific Gulf of Alaska, Aleutian Islands, and Bering Sea Transient Stock; AT1 Transient Stock; and West Coast Transient Stock) and two resident killer whale stocks (Eastern North Pacific Alaska Resident

Stock and Eastern North Pacific Northern Resident Stock). Grouping populations into stocks helps NMFS to manage the unique threats, habitats, human interactions, and to understand the population dynamics displayed by killer whales in Alaska. Detailed information on the status of killer whales and other NMFS managed species and stocks is available in the Alaska Marine Mammal Stock Assessment Reports, or SARs (Young et al. 2023), which are regularly updated with current information. NMFS has genetic information on killer whales in Alaska that indicates the current stock structure should be reassessed (Parsons et al. 2013); NMFS may revise Alaska killer whale stock structure in future publications and reports. In this technical memorandum, we used stocks as they are published in Young et al. (2023). The stock of entangled killer whales (Dahlheim, Cahalan and Breiwick 2022, Freed 2022) is listed (if known) as noted in the appendix of this technical memorandum.

Killer whales in Alaska face a range of anthropogenic threats. Environmental contaminants, such as persistent organic pollutants, can accumulate in killer whale tissues and have negative health impacts (Lawson et al. 2020, McCormley et al. 2021). Noise pollution, such as from vessel traffic, can interfere with killer whale communication and echolocation abilities (Williams et al. 2014). Additionally, killer whales can become entangled in fishing gear, marine debris, or other materials, which can lead to injury or death (Dahlheim, Cahalan and Breiwick 2022).

Entanglements occur when anthropogenic material becomes wrapped around, hooked into, or otherwise associated with the outside of the body of the animal. Entanglements can also include cases when an animal has ingested gear including hooks, line, or other marine debris (NMFS 2022b). Entanglements are a stressor of concern because of the threat posed to the animal's life and health and collectively have the potential for population level impacts (MMPA, Title IV; 16 USC §§ 1421). Marine mammal entanglements are also detrimental to the fishers who incur financial and material loss when their gear becomes lost or damaged by the interaction (Peterson et al. 2014, Tixier et al. 2020).

Killer whale entanglements pose unique challenges because they are sometimes precipitated by depredation activity (i.e., when killer whales are attracted to either the bait or the catch of fishers (Fader, Elliott and Read 2021). Longline fisheries are especially susceptible to depredation (Gilman et al. 2006), and killer whales have been extensively documented depredating longline catches (Hamer, Childerhouse and Gales 2012). Killer whales are also known to depredate net fishing such as purse seines, gillnets, and trawl nets, as well as collapsible style pots (e.g., Slinky™ pots), troll gear, and sport fishing gear (Mul et al. 2020, Bonizzoni et al. 2022). In Alaska waters, killer whales depredate multiple fisheries including sablefish (*Anoplopoma fimbria*), Greenland turbot (*Reinhardtius hippoglossoides*), and Pacific halibut (*Hippoglossus stenolepis*) that are fished with pots, nets, and line (Dahlheim 1988, Peterson et al. 2014, Belonovich et al. 2021). Killer whale depredation behaviors associated with any commercial fisheries can result in entanglement and subsequent injury or mortality of the whale (Dahlheim, Cahalan and Breiwick 2022, Freed 2022).

Killer whales are also known to follow fishing vessels and attempt to depredate gear or feed on offal and discarded catch that are returned to the sea. This introduced food source can serve as positive reinforcement and encourage killer whales to follow fishing vessels as they fish and increase the likelihood of killer whales becoming entangled in gear (Dahlheim, Cahalan and Breiwick 2022).

Killer whales are intelligent, curious, and playful animals and are capable of learning and experimentation (Úbeda et al. 2019, Marino et al. 2020). They may interact with gear intentionally for a variety of reasons not yet understood by scientists. Killer whales sometimes interact with vessels, individually or in groups (Esteban et al. 2022). Their curiosity and experimentation may result in negative interactions, including entanglements with fishing gear or marine debris.

NMFS has documented killer whale entanglements through a variety of means established under three primary programs for several decades. First, the Alaska Marine Mammal Stranding Network collects data on cetacean entanglement reports in Alaska, including reported killer whale entanglements. The network falls under the direction of NMFS's National Marine Mammal Health and Stranding Response Program (MMHSRP), which was formalized under Title IV in the 1992 amendments to the Marine Mammal Protection Act of 1972 (MMPA), codified at 16 USC, Ch. 31, Subch. V. The MMPA mandates that NMFS track health trends of marine mammals and conduct emergency responses for marine mammals in distress when possible (MMPA; 16 USC §§ 1421). Reports contributed by members of the public to stranding network members are referred to as AK Marine Mammal Stranding Network (AK MMSN) reports in this technical memorandum.

The second source of entanglement reports is the Marine Mammal Authorization Program (MMAP). The MMAP was created in the 1994 amendments to the MMPA and allows exceptions to the take moratorium for take that is incidental to commercial fishing activity. MMPA section 118 requires that all commercial fishery vessel owners or operators report all incidental mortality or injury of marine mammals in the course of fishing operations to NMFS within 48 hours after the end of the fishing trip for the incidental take to be covered by the MMAP. In this technical memorandum, we will refer to these reports as MMAP reports.

The third method for documenting killer whale entanglements is through the North Pacific Observer Program (Observer Program) which provides the regulatory framework for NMFS-certified observers to collect data on groundfish and halibut fisheries. Since the 1980s, NMFS has deployed observers on domestic commercial groundfish fishing boats in the Federal waters off Alaska. These observers' first prioritize documentation of marine mammal interactions with the vessel or gear including any injury, mortality, or entanglement they witness. The nature of the reports provided by the observers was modified in 2007 to include new data fields to assist NMFS in making determinations of injury severity, and the program was restructured in 2013 to provide wider coverage of the fisheries, including deploying observers on vessels targeting halibut. These programmatic modifications are reflected in the reports of entanglements provided by the Observer Program. In this technical memorandum these reports are referred to as Observer Program reports.

NMFS reviews and evaluates marine mammal interaction reports from all sources and makes determinations regarding injury severity (i.e., whether the animal is more likely than not to die because of its injury) in accordance with NMFS' Process and Guidelines for Distinguishing Serious from Non-Serious Injury of Marine Mammals (88 FR 7957, February 7, 2023). Estimates of total mortality and serious injury are considered removals from the population and are compared against the stock's potential biological removal (PBR) level in the SARs as part of the evaluation of the stock's status. Additional information regarding injury and mortality reports and their subsequent severity determinations can be found in the annual NOAA technical memorandum series, "Human-Caused Mortality and Injury of NMFS-Managed Alaskan Marine Mammal Stocks" (Freed 2022).

Data from all three programs are presented in this technical memorandum. Because different reporting requirements have been instituted at multiple times in NMFS' history, cases contained in this paper are subject to different biases according to reporting sources and case types. We are presenting all reports from the three programs; however, these are to be considered minimum estimates because not all entanglements are observed and not all witnessed entanglements are reported. Increases in reports in this technical memorandum could reflect actual increases in entanglement incidence or increases in reporting. Additionally, while this report includes only data from entanglements that occurred in Alaska waters, there have been cases of animals from Alaska killer whale stocks becoming entangled in other regions (e.g., other parts of the U.S. West Coast). More information on killer whales entangled outside of Alaska waters can be found in "Large whale entanglements off the U.S. West Coast, from 1982-2017" (Saez, Lawson and DeAngelis 2021).

# Killer Whale Entanglement Reports

## Report Sources

Information on the 37 cases of killer whale entanglement reported herein was collected by NMFS from a variety of sources through the three primary programs discussed above (AK Marine Mammal Stranding Network, MMAP, and Observer Program) from 1991 to 2022 (Appendix). Cases that were reported both through the MMAP and Observer Program (cases 9, 10, 11, 12, 14, 15, 16, 17, 18, 19, and 37) are primarily categorized in this technical memorandum as MMAP to capture the fishers' efforts to self-report. Case 13 was initially reported through the AK Marine Mammal Stranding Network and subsequently reported through MMAP. Thirteen total incidents were self-reported by fishers through the MMAP, while seven reports were submitted by the public solely to the AK Marine Mammal Stranding Network. Federal commercial fisheries observers reported 17 entanglements from 1991 to 2022 that were not accompanied by MMAP reports. The amount of information provided in the reports varies by source, with AK Marine Mammal Stranding Network reports generally including the most detail. Personally identifiable and other confidential information has been removed from all cases included in this report.

Different reporting requirements have been instituted over time, resulting in a shift in the predominant reporting sources as well as a general increase in case reporting in more recent years (**Figure 1**). The distribution likely reflects evolving reporting requirements and may not indicate a trend in actual entanglement events. Additionally, advances in camera technology, real-time access to phone service by the public to facilitate reporting, and greater dissemination of information regarding entanglement reporting in the decades since NMFS began tracking entanglements, have also changed the nature and frequency of reports and the reliability of the data.

The geographic location of reports is displayed in **Figure 2**. MMAP and Observer Program data are displayed as a density map to prevent identification of individual vessels. AK Marine Mammal Stranding Network reports are displayed at the exact latitude and longitude from the report and are depicted as killer whale icons. Regions are outlined in different colors.

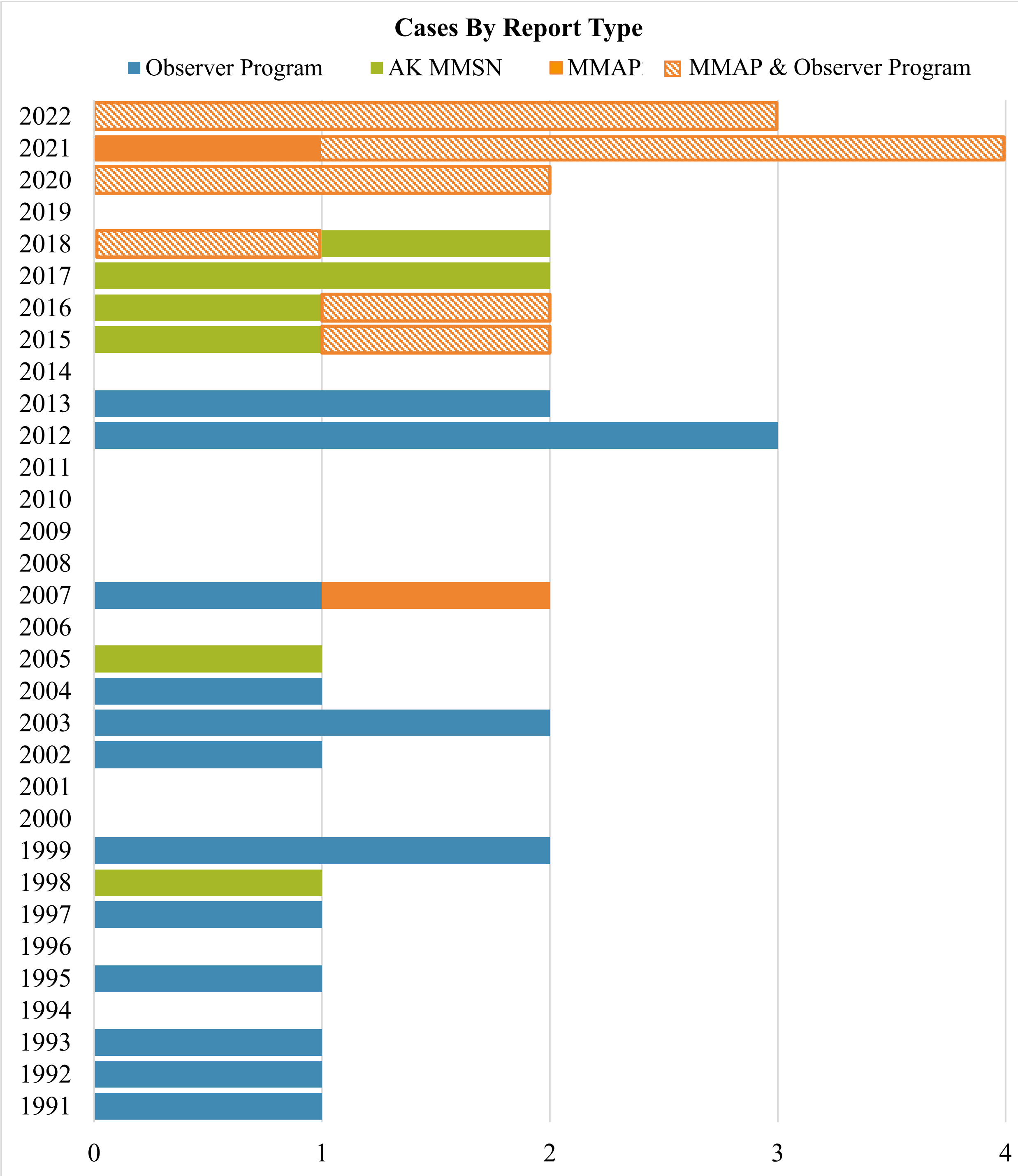


***Figure 1. Killer whale entanglement reports in Alaska from 1991 to 2022 (N=37). Yearly totals are depicted by the bars next to each year. The colors correspond with the chosen categorization of the report source. Two AK Marine Mammal Stranding Network reports (2015, 2017) were determined to not be entanglements (i.e., kelp).***

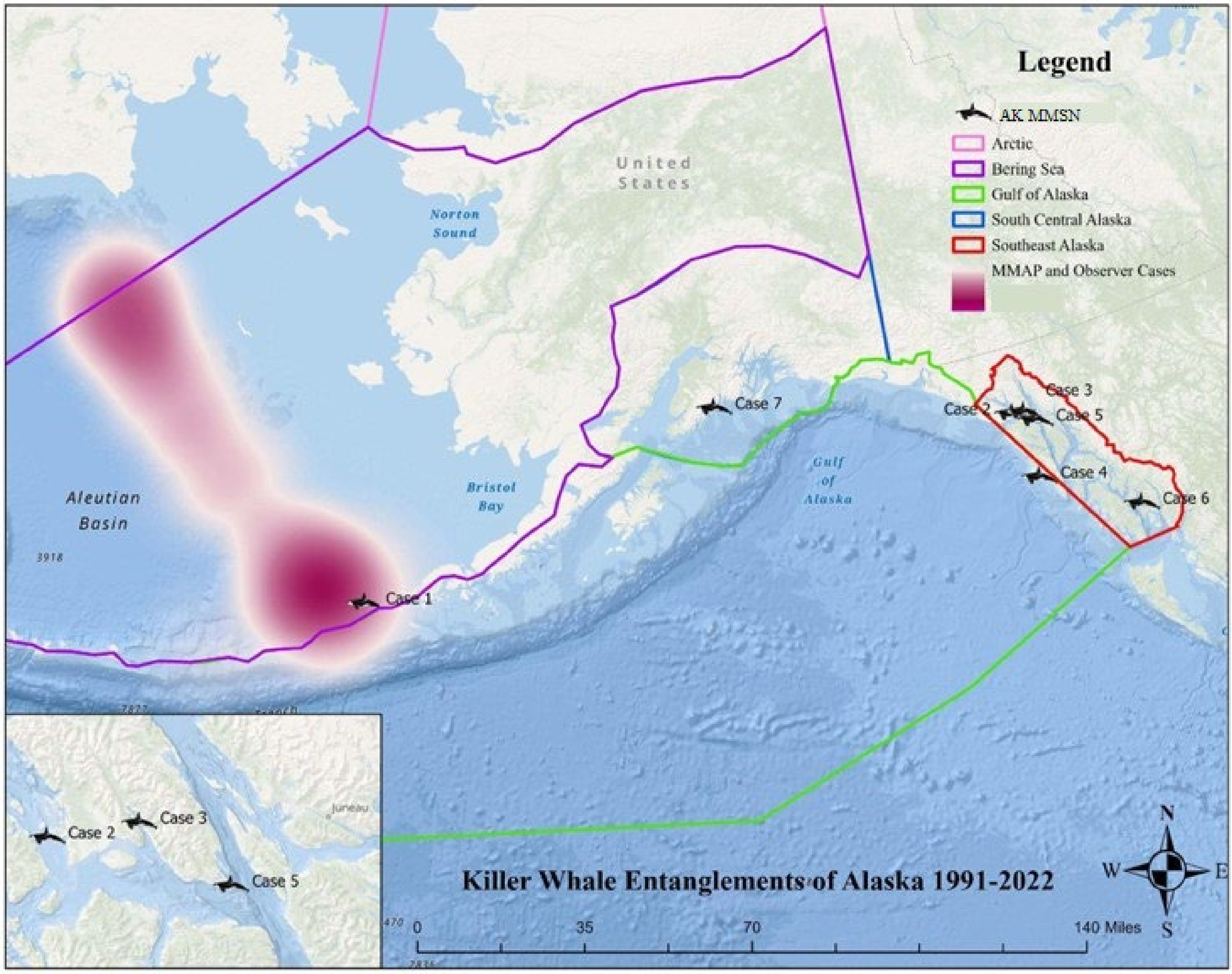


*Figure 2. Map of killer whale entanglement cases in Alaska from 1991-2022. Case density is depicted on a white (minimum) to purple (maximum) scale and rendered over a radius of 60 decimal degrees to preserve anonymity of MMAP and Observer Program reports (n=30). AK Marine Mammal Stranding Network cases are shown as points (whale icon, n=7), cases 5 and 7 were determined to not be entangled (i.e., kelp). The inset at the lower left provides detail on the location of cases 2, 3, and 5.*

# Case Studies

The cases in this technical memorandum are categorized by entangling material: trawl nets, longlines, pot gear, miscellaneous, and natural source (non-anthropogenic) non-entanglements (**Figure 3**). Cases that could be attributed to a commercial fishery are shown in (**Figure 4**). See the Appendix for all cases.

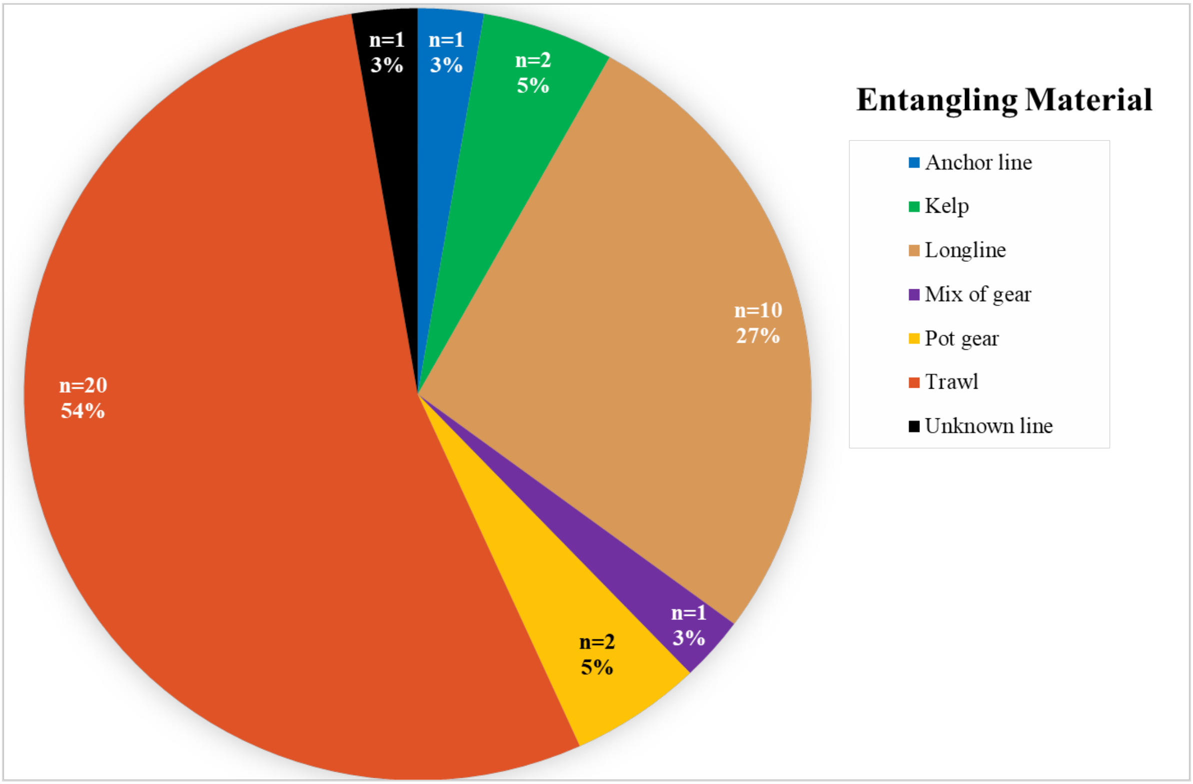


***Figure 3. Material involved in the 37 reported killer whale entanglement reports in Alaska, 1991-2022, analyzed for this technical memorandum. Data sources described in the "Report Sources" section. The two kelp cases were determined to not be entangled.***

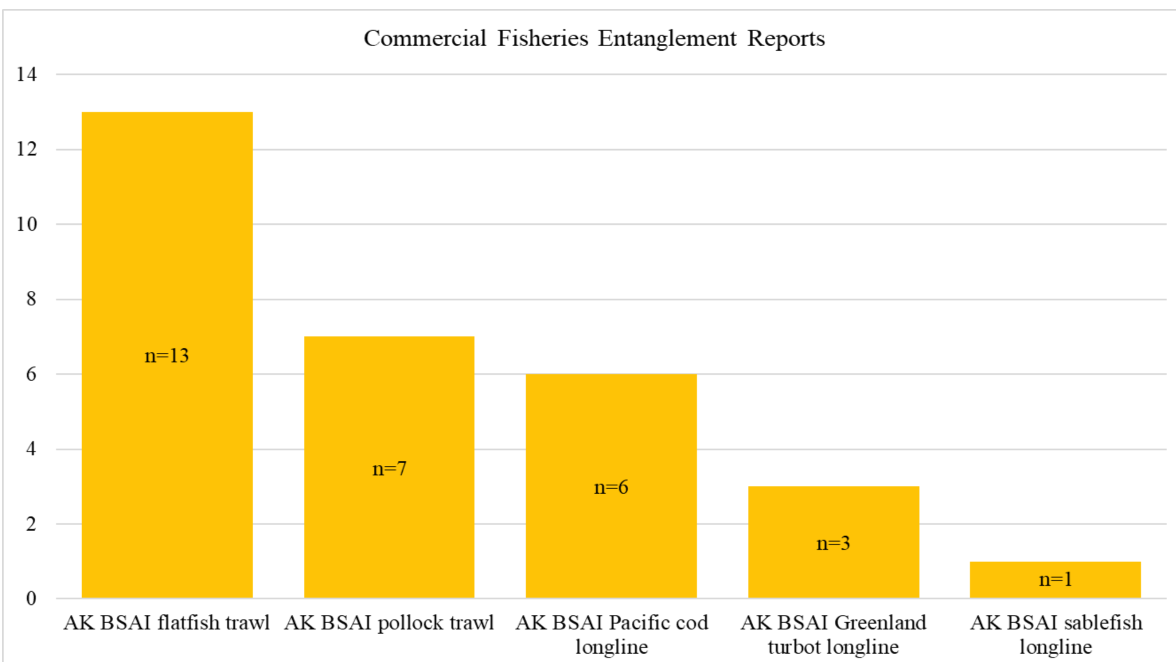


***Figure 4. Killer whale entanglements attributed to Federal (n=30) commercial fisheries in Alaska, 1991-2022. Data sources are described in the "Report Sources" section.***

## Case Studies: Trawl Net Entanglements

Trawlers catch fish by towing trawl nets along the seafloor or through the water column and are classified as non-pelagic trawls or pelagic trawls, respectively (58 FR 39680, July 26, 1993). Catch is funneled into the cone shaped net and becomes trapped in the codend (NMFS 2022c). Entanglements can occur when killer whales interact with the net as they are feeding on offal or discards, or when killer whales enter the net either while feeding in front of it or to depredate the catch and are unable to escape.

Trawl net entanglements comprise the majority (54%) of reported killer whale entanglements in Alaska (**Figure 3**). Of these reports, 65% (n = 13) were associated with commercial flatfish trawls (non-pelagic) and 35% (n = 7) were associated with commercial pollock trawls (pelagic; **Figure 4**). Ten of the 20 (50%) trawl-entangled killer whales had a determined age class (**Table 1**). Of these ten whales, 30% (n=3) were adults and 70% (n=7) were subadults or calves. For the 14 out of 20 trawl entangled whales with a sex determination, 50% were male and 50% were female. Killer whales entangled in trawl nets in Alaska have a low chance of survival: of the cases reported here, only 25% (n = 5) were released alive, and all of those whales had a serious injury determination. All the whales that were released alive likely entered the net while it was being hauled to the surface.

Trawl entanglements can involve multiple whales. Cases 11 and 12 involved one male and one female that died in the same haul. The whales appeared freshly dead after the net was hauled onboard, and the crew used a crane to remove them for examination. The animals likely asphyxiated after becoming trapped inside the net. This case was reported through both the MMAP and the Observer Program. The two cases are classified as an MMAP report in this technical memorandum. Similarly, cases 14 and 15 involved a mother and dependent calf tandem entanglement. The mother was deceased by the time the net was brought to the surface, but the calf was still alive. The mother's carcass and the live calf were disentangled and returned to the ocean. At the time of this report, the calf is considered "disentangled" and this interaction is considered a serious injury, however an official serious injury determination has not yet been made for this case. The information for these cases will be published in the next "Human-Caused Mortality and Injury of NMFS-managed Alaska Marine Mammal Stocks" publication.

In trawl entanglement cases where the whale was still alive when the net was hauled, fishers disentangled and released them. All the animals released alive from trawl nets were determined to be seriously injured per the national procedural directive criteria for serious injury determination (**Table 1**). Small cetaceans (including killer whales) brought on the vessel deck following an interaction are considered seriously injured because the individual is subject to a high risk of later death due to capture myopathy, aspiration, or hidden injuries (88 FR 7957, February 7, 2023).

Disentanglement tactics used by fishers included cutting or unzipping the length of the net and allowing the whale to swim out or releasing the whale down the stern ramp if hauled aboard. The federal observer who documented case 30 reported that the crew dumped fish out of the net until the whale's flukes were exposed, and then pulled the net backwards until the killer whale was on the stern ramp. The crew then used a winch to lift the net, enabling the whale to slide down the stern ramp and into the water. The observer who documented case 34 reported a live male killer whale entangled in the codend of the net. After the net was brought on deck it was unzipped and then resubmerged, but the whale was not able to swim out. The net was brought on deck a second time and unzipped from the bottom end of the codend and released back into the water and the whale was able to swim out of the net. Blood was observed on deck, but the extent of the injuries to the whale was unknown. The observer who documented case 36 reported a live calf caught in the trawl net. The crew cut the net open and pushed the whale down the ramp, after which it swam off and rejoined the pod. Killer whales in cases 34 and 36 were brought onto vessels, and the incidents were classified as serious injuries (Helker, Allen and Jemison 2015) but it is unknown if the whales sustained life-threatening injuries.

When killer whale flukes or fins were entangled in the mesh, the affected parts of the net also needed to be cut before the whale could be released. The observer who documented case 35 reported that a live adult male killer whale became caught in the opening of the trawl net as it was being hauled onboard. The crew cut the net to try and get the whale free, but the webbing of the net was caught around the dorsal fin. They used a crane to get the net off the fin. The flukes were also entangled in the net and more of the net was cut to free them. Once the killer whale was released back into the water, the observer noted that the animal exhibited abnormal behavior and stayed near the surface for a while. Approximately 15 minutes later, the whale swam towards other killer whales near the boat.

Case 13 was originally reported to NMFS through the AK Marine Mammal Stranding Network and then subsequently reported through the MMAP and is presented under MMAP in the figures and tables above.

***Table 1. Trawl net entanglement reports for killer whales in Alaska from 1991-2022. Cases are presented in chronological order.***

| Date | Case Number | Subarea | Initial condition | Age Class | Sex | Length (ft.) | Commercial Fishery | Entanglement Outcome |
|---|---|---|---|---|---|---|---|---|
| 18-Jun-91 | 20* | Bering Sea | Dead | Unknown | Female | 18.9 | AK BSAI Pollock trawl | Died |
| 21-Jan-92 | 21* | Bering Sea | Dead | Unknown | Female | 17.4 | AK BSAI Pollock trawl | Died |
| 22-Mar-93 | 22* | Bering Sea | Dead | Unknown | Unknown | Unknown | AK BSAI flatfish trawl | Died |
| 15-Oct-97 | 24* | Bering Sea | Dead | Unknown | Male | 23.6 | AK BSAI Pollock trawl | Died |
| 20-Aug-99 | 26* | Bering Sea | Dead | Subadult | Female | 18.8 | AK BSAI Pollock trawl | Died |
| 12-Mar-02 | 27* | Bering Sea | Dead | Subadult | Male | Unknown | AK BSAI Pollock trawl | Died |
| 20-Mar-03 | 29* | Bering Sea | Dead | Subadult | Female | 13.5 | AK BSAI Pollock trawl | Died |
| 29-Jul-04 | 30* | Bering Sea | Alive | Unknown | Unknown | Unknown | AK BSAI flatfish trawl | Disentangled; Serious injury |
| 30-Jul-12 | 34* | Bering Sea | Alive | Unknown | Male | Unknown | AK BSAI flatfish trawl | Disentangled; Serious injury |
| 5-Jul-13 | 35* | Bering Sea | Alive | Adult | Male | Unknown | AK BSAI flatfish trawl | Partial disentanglement; Serious injury |
| 16-Jul-13 | 36* | Bering Sea | Alive | Calf | Unknown | Unknown | AK BSAI flatfish trawl | Disentangled; Serious injury |
| 25-Jul-18 | 37*† | Bering Sea | Dead | Unknown | Male | 25.8 | AK BSAI flatfish trawl | Died |
| 30-Apr-20 | 12*† | Bering Sea | Dead | Unknown | Female | 19.9 | AK BSAI flatfish trawl | Died |
| 30-Apr-20 | 11*† | Bering Sea | Dead | Subadult | Male | 14.4 | AK BSAI flatfish trawl | Died |
| 22-May-21 | 15*† | Bering Sea | Alive | Calf | Female | 9.8 | AK BSAI flatfish trawl | Disentangled; Serious injury |
| 22-May-21 | 14*† | Bering Sea | Dead | Adult | Female | 19.6 | AK BSAI flatfish trawl | Died |
| 7-Jul-21 | 16*† | Bering Sea | Dead | Adult | Unknown | Unknown | AK BSAI flatfish trawl | Died |
| 22-Sep-21 | 13^† | Bering Sea | Dead | Subadult | Male | 16 | Trawl | Died |
| 11-Jun-22 | 17*† | Bering Sea | Dead | Unknown | Unknown | Unknown | AK BSAI flatfish trawl | Died |
| 14-Jul-22 | 18*† | Bering Sea | Dead | Unknown | Unknown | Unknown | AK BSAI flatfish trawl | Died |

**** Indicates cases reported through the Observer Program***
***† Indicates cases reported through the MMAP***
***^ Indicates cases reported through the Alaska Marine Mammal Stranding Network***
***BSAI= Bering Sea, Aleutian Islands***

## Case Studies: Longline Entanglements

Longliners catch fish by deploying a horizontal line along the seafloor (the groundline) between two vertical lines, known as buoy lines or set lines, connected to buoys at the surface. The groundline carries a string of baited hooks and is weighted to the seafloor (NMFS 2022c). While some longline fisheries use pots or traps, all longlines reported in this technical memorandum were using hooks on their gear at the time of the entanglement.

Longline entanglements were the second most frequent type of killer whale entanglements (**Figure 3**). Killer whale entanglement reports were associated with commercial longlines targeting Pacific cod (60%), Greenland turbot (30%), and halibut and sablefish (10%) (**Figure 4**). The age class was determined for four of the 10 longline entangled killer whales; three were determined to be subadults and one was a non-calf. The sex of killer whales entangled in longlines was known in four reports: half (2) were male, and half (2) were female (**Table 2**). Killer whales reported entangled in longlines have a very low chance of survival. Of the cases reported here, 20% (2 out of 10) were alive when released from the entanglement, one of which was considered seriously injured and one considered non-seriously injured (i.e., more likely than not to survive).

Both the buoy lines and groundlines of longline operations are an entanglement risk, but all reported longline-related cases in Alaska from 1991-2022 involved groundline entanglements. This is likely because killer whales depredate on the hooked catch of the groundline hooks. The groundline was often wrapped around the body or specific body parts of the whales. In case 8, the line was wrapped around the animal and there was visible blood where hooks perforated the animal. The fishers reporting case 10 found a dead subadult killer whale that was wrapped in the line multiple times. There were no visible lacerations or blood.

Fishers reporting case 19 found a subadult killer whale entangled in the longline gear. When the line was hauled to the surface the whale was deceased and the groundline was wrapped around the flukes. The fishers cut the line and disentangled the carcass, and it was carried away by the current. The observer of case 33 reported a dead subadult killer whale with the groundline wrapped around the body of the whale and caught behind the pectoral fins. As with trawl entanglement mortalities, cause of death in longline entanglement cases was assumed to be asphyxiation.

In the cases where killer whales were released alive from longline entanglements, they likely became entangled shortly before haul back of the line. In case 9, fishers reported that their groundline became entangled around the peduncle and flukes of a live killer whale. When the animal was hauled alongside the fishing vessel, the fishers were able to release the whale within three to four minutes. The captain reported that afterwards the killer whale "wasn't moving very much" and it was unclear whether gear remained on the animal. This case was classified as a serious injury (Helker et al. 2017) and a partial disentanglement. The single report of a successful disentanglement response by a vessel crew in case 32 required cutting the entire line at the crucifier and hauling the gear aboard from the other end. The whale was not brought on deck during the disentanglement effort. Details about the condition of the whale after its release were not available but the animal was determined to be non-seriously injured (Helker, Allen and Jemison 2015).

***Table 2. Longline entanglement reports for killer whales in Alaska from 1991-2022. Cases are presented in chronological order.***

| Date | Case Number | Subarea | Initial condition | Age Class | Sex | Length (ft.) | Commercial Fishery | Entanglement Outcome |
|---|---|---|---|---|---|---|---|---|
| 4-Sep-95 | 23* | Bering Sea | Dead | Unknown | Female | Unknown | AK BSAI Pacific cod longline | Died |
| 11-May-99 | 25* | Bering Sea | Dead | Unknown | Male | 21.5 | AK BSAI Greenland turbot longline | Died |
| 9-Sep-03 | 28* | Bering Sea | Dead | Subadult | Female | 14.1 | AK BSAI Pacific cod longline | Died |
| 24-Jun-07 | 31* | Bering Sea | Dead | Unknown | Male | Unknown | AK BSAI Greenland turbot longline | Died |
| 4-Nov-07 | 8† | Gulf of Alaska | Dead | Unknown | Unknown | Unknown | AK BSAI Sablefish longline | Died |
| 2-Mar-12 | 32* | Bering Sea | Alive | Unknown | Unknown | Unknown | AK BSAI Pacific cod longline | Disentangled; Non-serious Injury |
| 12-Mar-12 | 33* | Bering Sea | Dead | Subadult | Unknown | Unknown | AK BSAI Pacific cod longline | Died |
| 19-Jul-15 | 9*† | Bering Sea | Alive | Unknown | Unknown | Unknown | AK BSAI Greenland turbot longline | Partial disentanglement; Serious Injury |
| 5-Jul-16 | 10*† | Bering Sea | Dead | Non-Calf | Unknown | 12-14 | AK BSAI Pacific cod longline | Died |

| Date | Case Number | Subarea | Initial condition | Age Class | Sex | Length (ft.) | Commercial Fishery | Entanglement Outcome |
|---|---|---|---|---|---|---|---|---|
| 7-Oct-22 | 19*† | Bering Sea | Dead | Subadult | Unknown | 15 | AK BSAI Pacific cod longline | Died |

**** Indicates cases reported through the Observer Program***
***† Indicates Cases reported through the MMAP***
***BSAI= Bering Sea, Aleutian Islands***

## Case Studies: Pot Gear Entanglements

Pot gear typically consists of submerged traps or pots that sit on the seafloor and are attached by a line to a buoy at the surface. The size, depth, length of line, and other specifics depend on the target species and there is large variation in pot parameters and associated gear (NMFS 2022c). Additionally, since 2019 there has been a significant shift from the use of traditional longline gear (i.e., hooks) to the use of pots (i.e., Slinky Pots ™) (NMFS 2022a). Killer whale entanglements with pot gear typically occur when the line connecting the pot to the surface buoy becomes wrapped around the body or a body part of the animal.

Pot gear entanglements made up 5% (n = 2) of reported killer whale entanglements in Alaska from 1991 to 2022 (**Figure 3**). These cases were reported to NMFS by the public through the AK Marine Mammal Stranding Network (**Table 3**). In both cases, the whale was able to tow the gear away from its set location. Case 3 was a report of a killer whale with a pot gear line wrapped around the peduncle with a towed buoy on twenty feet of line. The whale was accompanied by another whale, and both were swimming quickly. An unauthorized skiff-based disentanglement attempt was conducted by members of the public, but they were unable to make a close approach to the whale. The entangled whale and its companion were observed multiple times over the next couple of days, but it is unknown if the whale was able to release from the pot gear. This instance was classified as a serious injury (Helker et al. 2019, Freed 2022). This case demonstrates the difficulty in responding to towed entanglements or determining the outcome in free-ranging animals. Case 6 was a report of a killer whale entangled in personal recreational shrimp pot gear in Behm Canal in southern Southeast Alaska. It was reported by recreational fishers who observed the entangled whale and watched as it successfully self-released from the pot and around 300 ft. of line. The owner of the gear was identified based on buoy markings, and they confirmed the pot had been set in Moser Bay, about three miles away from where the killer whale self-released (**Figure 5**). It is unknown if the whale became entangled at the set location and towed the gear to Behm Canal or if the gear was displaced by other means and the entanglement occurred at the site of observation.

***Table 3. Pot gear entanglement reports for killer whales in Alaska from 1991-2022. Cases are presented in chronological order.***

| Date | Case Number | Subarea | Initial Condition | Age Class | Sex | Length (ft.) | Commercial Fishery | Entanglement Outcome |
|---|---|---|---|---|---|---|---|---|
| 4-Sep-16 | 3 | Southeast Alaska | Alive | Unknown | Unknown | Unknown | Unknown | Unknown; Serious Injury |
| 23-Sep-18 | 6 | Southeast Alaska | Alive | Unknown | Unknown | Unknown | Non-commercial | Self-release |

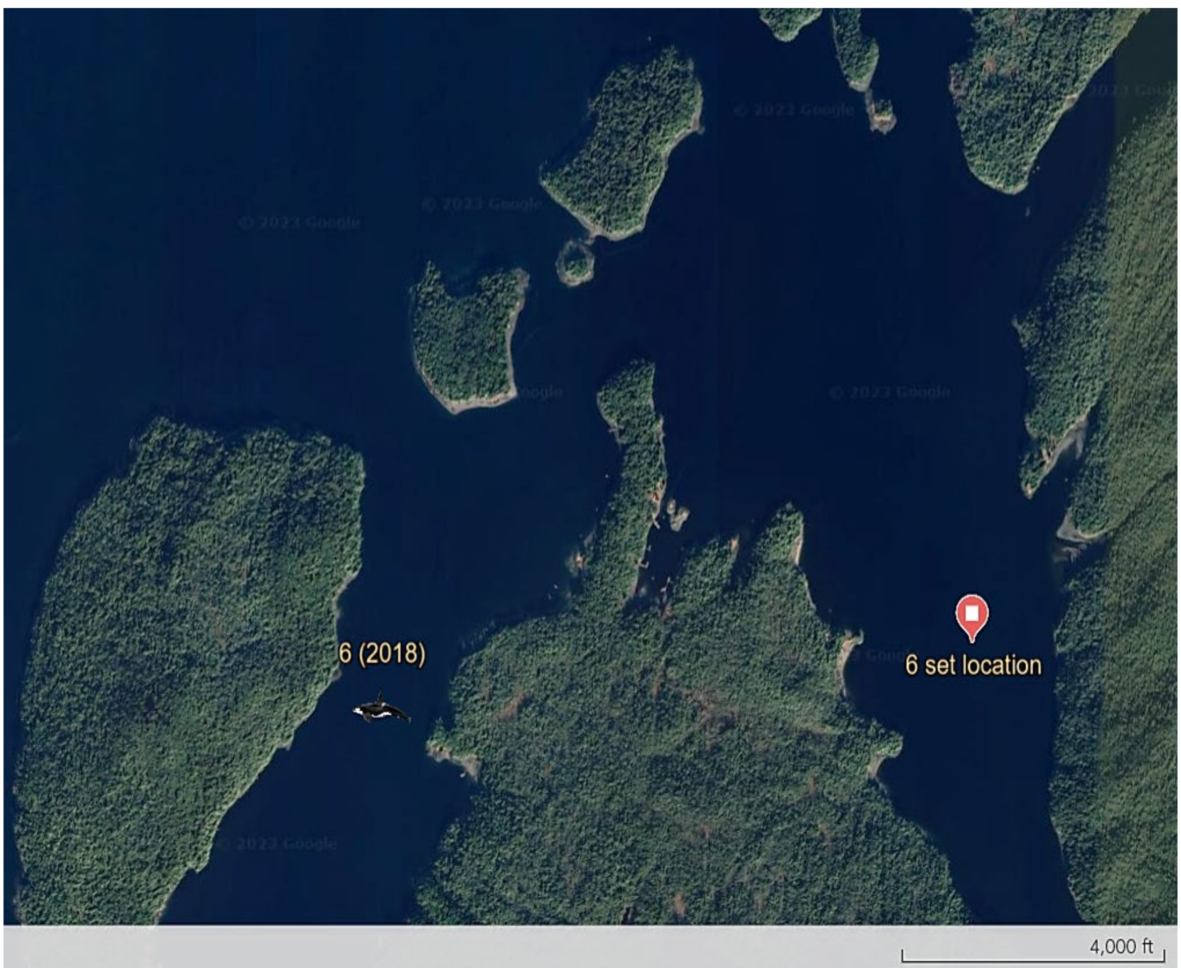


***Figure 5. Case 6: Map of the Behm Canal region with gear set location and location of observed entangled animal. The shortest distance the whale could have swum with the gear based on these two locations is three miles.***

## Case Studies: Miscellaneous Gear Entanglements

Three reports were related to gear types that only occurred once in these data sets (**Table 4**). These cases were reported to NMFS by the public through the AK Marine Mammal Stranding Network. Case 1 was a report from the crew of a fishing vessel north of Unimak that observed a moderately decomposed dead subadult (9-26ft) killer whale with a line around the body posterior to the dorsal fin. The origin of this gear remains unknown. Two vessels' crew members made independent drawings of their observations one day apart (**Figure 6**, **Figure 7**).

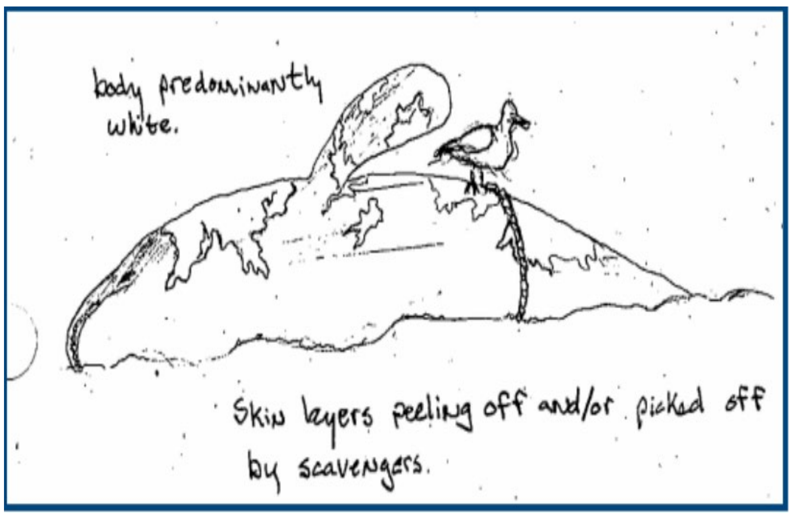


***Figure 6. Case 1: Illustration of the entangled killer whale, Report 1.***

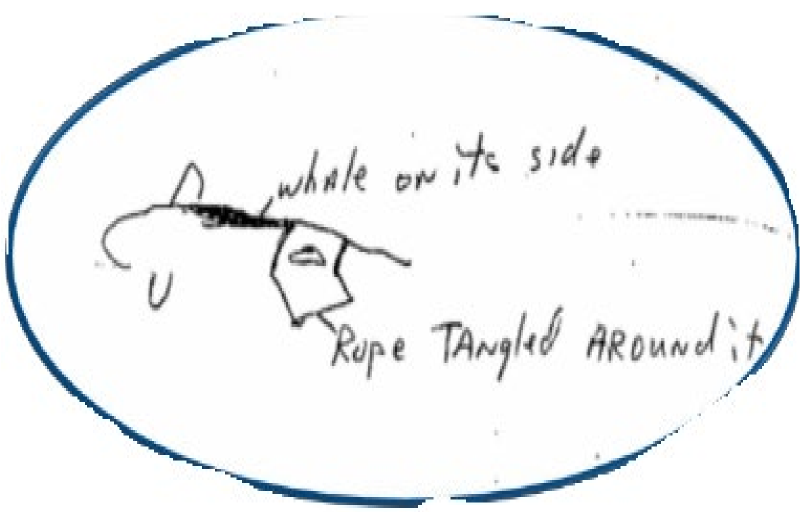


***Figure 7. Case 1: Illustration of the entangled killer whale, Report 2.***

Case 2 was reported to NMFS by Glacier Bay National Park staff in August 2005. A calf killer whale carcass was found stranded on a beach in Glacier Bay National Park with fishing gear in its mouth (**Figure 8**, **Figure 9**). The subsequent necropsy revealed four separate pieces of fishing gear in the mouth, esophagus, and stomach of the whale. One straight hook with a monofilament line and plastic lure was found in the mouth (**Figure 10**). Experts analyzed this gear and believed it to be salmon troll fishing gear. A circle hook and heavy-duty twine gangion with clip were found lodged in the esophagus (**Figure 11** and **Figure 12**). Experts believe this gear to be commercial halibut fishing gear. The necropsy also revealed two pieces of gear in the stomach: an additional straight hook, and an additional circle hook with twine gangion and a snap-style clip (**Figure 13**). Experts were not able to determine the specific fisheries involved based on the gear because commercial and personal users often fish with the same or similar gear. Additionally, subsequent tooth analysis by an aging expert determined the whale to be three years old.

***Figure 8. Case 2: Carcass with visible gear in its mouth. Photo provided by Alaska SeaLife Center necropsy report; AK Stranding Report 2005054.***

***Figure 9. Case 2: Carcass with visible gear in its mouth. Photo provided by Alaska SeaLife Center necropsy report; AK Stranding Report 2005054.***


***Figure 10. Case 2: Gear found in mouth. Photo provided by Glacier Bay National Park, Christine Gabriele.***

*Figure 11. Case 2: Gear found in esophagus. Photo provided by Glacier Bay National Park, Christine Gabriele.*


*Figure 12. Case 2: Gear found in esophagus. Photo provided by Glacier Bay National Park, Christine Gabriele.*


***Figure 13. Case 2: Gear found in stomach. Photo provided by Alaska SeaLife Center necropsy report.***

Case 4 was recorded and posted to YouTube by a member of the public. The video clip shows a killer whale interacting with a line and dragging a buoy that was attached a skiff (**Figure 14**, **Figure 15**). It is unknown if the whale is entangled or if it held the line in its mouth, or what precipitated the interaction. Although it is not clear if this occurrence is an entanglement, this behavior puts the animal near entangling materials and could inadvertently lead to an entanglement. We included this report in this technical memorandum to highlight how entanglements can come about, and the unique nature of killer whale entanglement sources.

The diversity of these cases demonstrate how killer whales can become entangled in a variety of uncommon scenarios. Their intelligence, curiosity, and complex behaviors can create various gear interactions that lead to negative outcomes for the animals and humans.

***Figure 14. Case 4: Screenshot of killer whale dragging a buoy with line likely in its mouth; taken from a YouTube video (Littlefield 2017).***

***Figure 15. Case 4: Screenshot of a killer whale swimming with line in its mouth; taken from a YouTube video (Littlefield 2017).***

***Table 4. Single occurrence gear type entanglement reports for killer whales in Alaska from 1991-2022. Cases are presented in chronological order.***

| **Date** | **Case Number** | **Subarea** | **Initial condition** | **Age Class** | **Sex** | **Length (ft.)** | **Type of Gear** | **Entanglement Outcome** |
|---|---|---|---|---|---|---|---|---|
| 17-Mar-98 | 1 | Bering Sea | Dead | Non-Calf | Unknown | 9-26 | Unknown line | Died |
| 26-Aug-05 | 2 | Southeast Alaska | Dead | Calf | Female | 11.76 | Mix of gear | Died |
| 23-Jul-17 | 4 | Southeast Alaska | Alive | Adult | Unknown | Unknown | Anchor line | Unknown |

## Case Studies: Natural Source Non-Entanglements

NMFS periodically receives reports of killer whales "entangled" in what is later determined to be kelp, a natural source of materials that becomes wrapped around the animals (**Figure 16**, **Figure 17**). On the West Coast, there have been killer whale entanglement reports that were assessed, and it was found that the killer whale was entangled in intestines (Saez, Lawson and DeAngelis 2021). NMFS does not consider these non-anthropogenic sources to be harmful or lethal but does assess them when reports are received to confirm that the entangling materials are natural and not anthropogenic. The inclusion of these reports in the dataset is inconsistent over time, however there are two reports in the dataset included in this technical memorandum (**Table 5**). In both cases, the reporting parties were concerned that the whales may be entangled in lines. However, upon review of photographs, NMFS determined that the material was kelp. The actual occurrence of observed kelp "entanglements" is thought to be much higher than the two cases (5% of the total) reported in this document; many of these instances are either not shared with NMFS by the reporting party or were not included in the database records. Rubbing on beaches and kelp is a normal behavior for killer whales. These cases are important to highlight because they may demonstrate the animals' natural behavior of interacting with kelp (e.g., play or reward-based behaviors). Also, mariculture of marine algae and seaweeds is on the rise which could put killer whales in increased proximity to lines covered in marine algae. Killer whales have the potential to interact with kelp farms' anthropogenic material as well as crops. These reports also highlight the importance of reviewing photo(s) and case details to properly assess and characterize the entanglement (e.g., what appears to be lines is not kelp).

*Table 5. Kelp "entanglement" reports for killer whales in Alaska from 1991-2022. Cases are presented in chronological order.*

| Date | Case Number | Subarea | Initial condition | Age Class | Sex | Length (ft.) | Source | Entanglement Outcome |
|---|---|---|---|---|---|---|---|---|
| 3-Aug-15 | 5 | Southeast Alaska | Alive | Non-Calf | Unknown | Unknown | Non-fishery | Confirmed not entangled |
| 30-Jul-17 | 7 | South Central Alaska | Alive | Adult | Male | Unknown | Non-Fishery | Confirmed not entangled |

*Figure 16. Case 5: Killer whale observed August 3, 2015, off Point Couverden, Lower Lynn Canal, Alaska. The substance on the dorsal fin of the whale in the photo was determined to be kelp.*

**Figure 17. Case 7: Killer whale observed on July 30, 2017, near Chat Island in Aialik Bay, Alaska. The substance on the flukes of the whale was determined to be kelp. Photo provided courtesy of John Coffey.**

# Results and Discussion

Twelve of the 37 reports were identified to stock (Appendix) (Dahlheim, Cahalan and Breiwick 2022, Freed 2022). Of these 12 cases, nine were from the Eastern North Pacific Alaska Resident stock; and three were from the Eastern North Pacific, Gulf of Alaska, Aleutian Islands, and Bering Sea Transient stock (**Figure 18**). The fisheries involved in these 12 cases are shown in **Figure 19**. The three transient killer whales were all entangled by trawl fisheries, while the nine resident killer whales were entangled by trawl, longline, and mixed gear (**Figure 19**). Genetic analysis performed on case 26 identified this killer whale to the AT1 haplotype. The AT1 haplotype indicates this killer whale is a member of the transient ecotype, but further genetic analysis would be needed to identify it to stock. It is not represented in the following figures that include stock identifications (**Figure 18**, **Figure 19**).

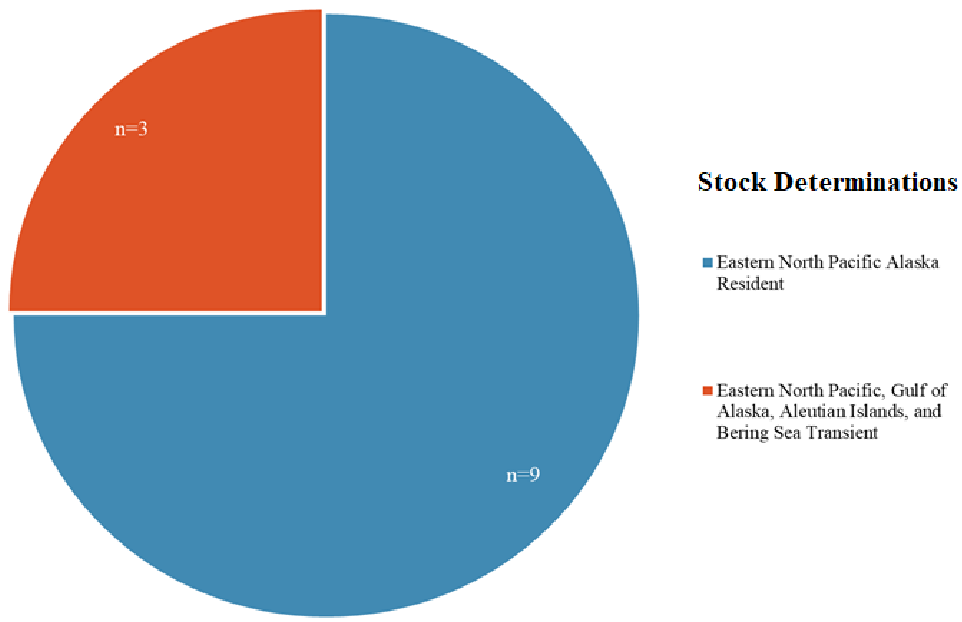


*Figure 18. Stock determinations for killer whale entanglements in Alaska from 1991-2022 (n=12). Stock determinations were only possible with certain fisheries interactions with observers trained to collect tissue from dead animals.*

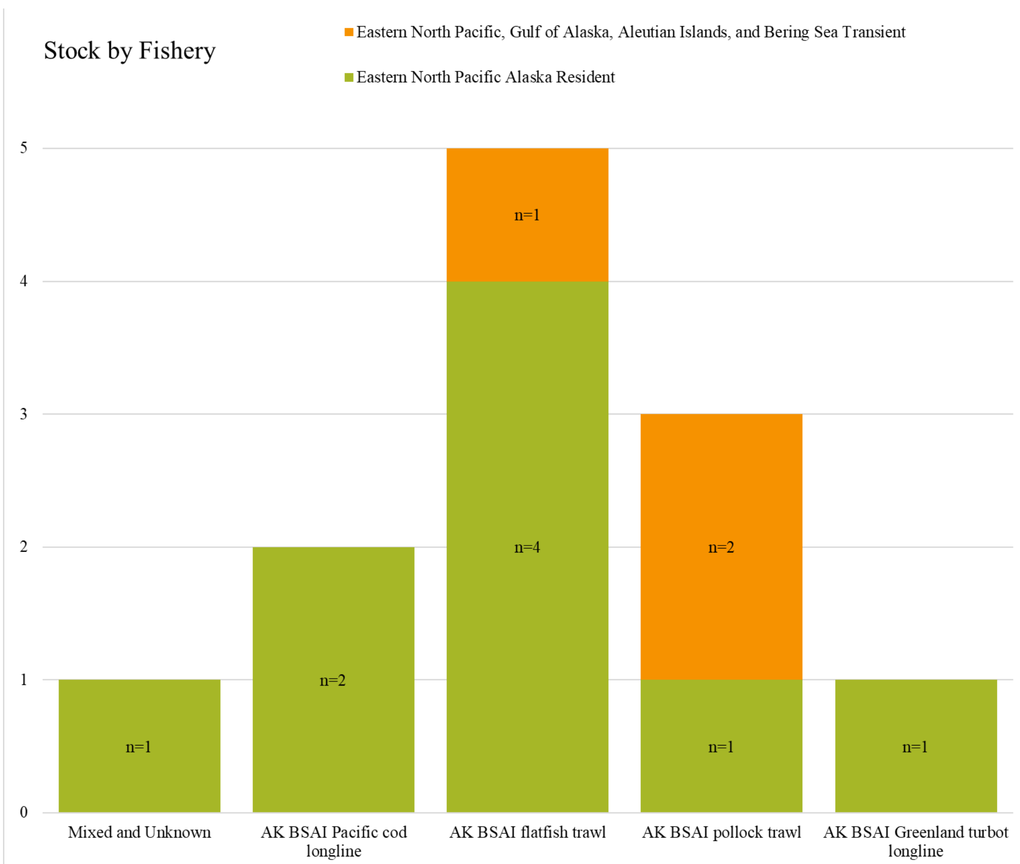


*Figure 19. Fishery breakdown for killer whale entanglement of known stock in Alaska from 1991-2022 (n=12).*

Most entanglement cases occurred during spring and summer (**Figure 20**), with 30% (n=11) taking place in July. In Alaska, these seasons correspond with higher on-water presence of recreational boaters, commercial and recreational fishers, and tourist boat operators. More people on the water increases the potential of someone observing and reporting an entanglement. Additionally, spring and summer correspond with open and active fishing in offshore and nearshore fisheries. Commercial fishing activity can be an attraction for killer whales if they are able to feed on the catch or discards associated with fishing (Fader, Elliott and Read 2021), although this association unfortunately leads to increased risk of entanglement.

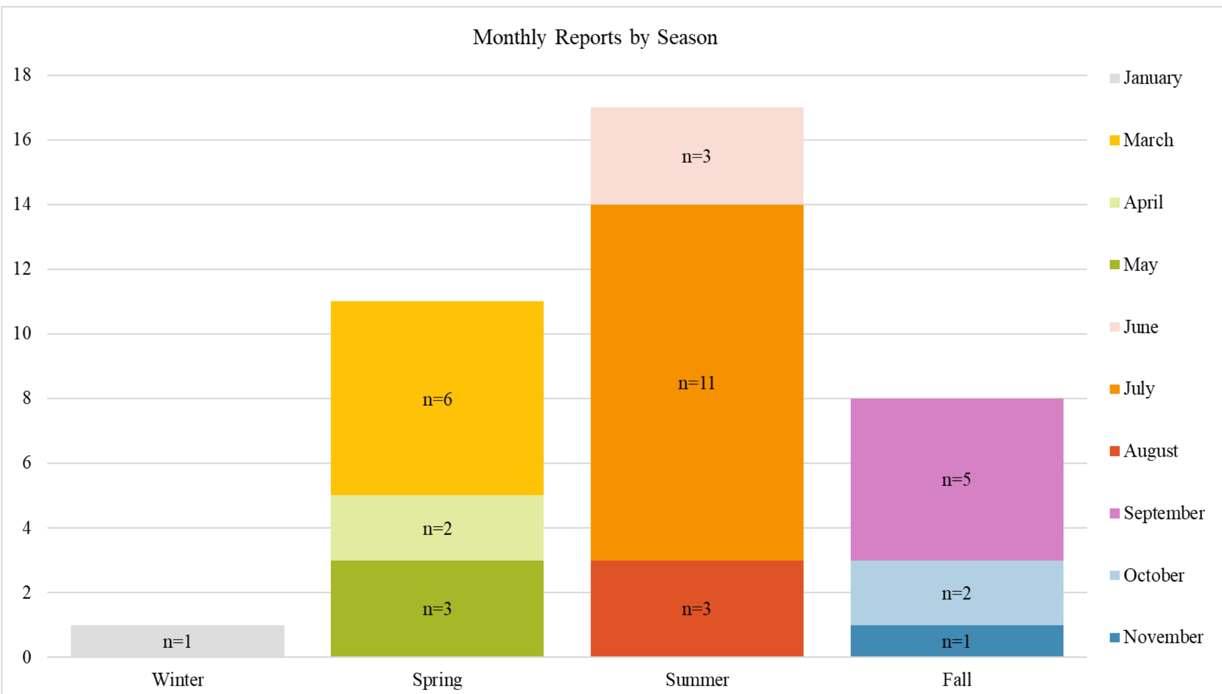

***Figure 20. Total reports of killer whale entanglements in Alaska from 1991-2022 by season (winter: Dec-Feb; spring: Mar-May; summer: Jun-Aug; fall: Sep-Nov).Colors correspond to month. N=37. The two kelp non-entanglements contribute one report in July and one report in August.***

Age class was determined in 44% (n=17) of the cases (Dahlheim, Cahalan and Breiwick 2022, Freed 2022). Of these, 70% (n=12) were juvenile: calf or subadult (**Figure 21**). Younger killer whales seem more likely to be involved in an entanglement. This may be due to lack of experience with the dangers of anthropogenic materials, curiosity, risky behaviors, or other factors.

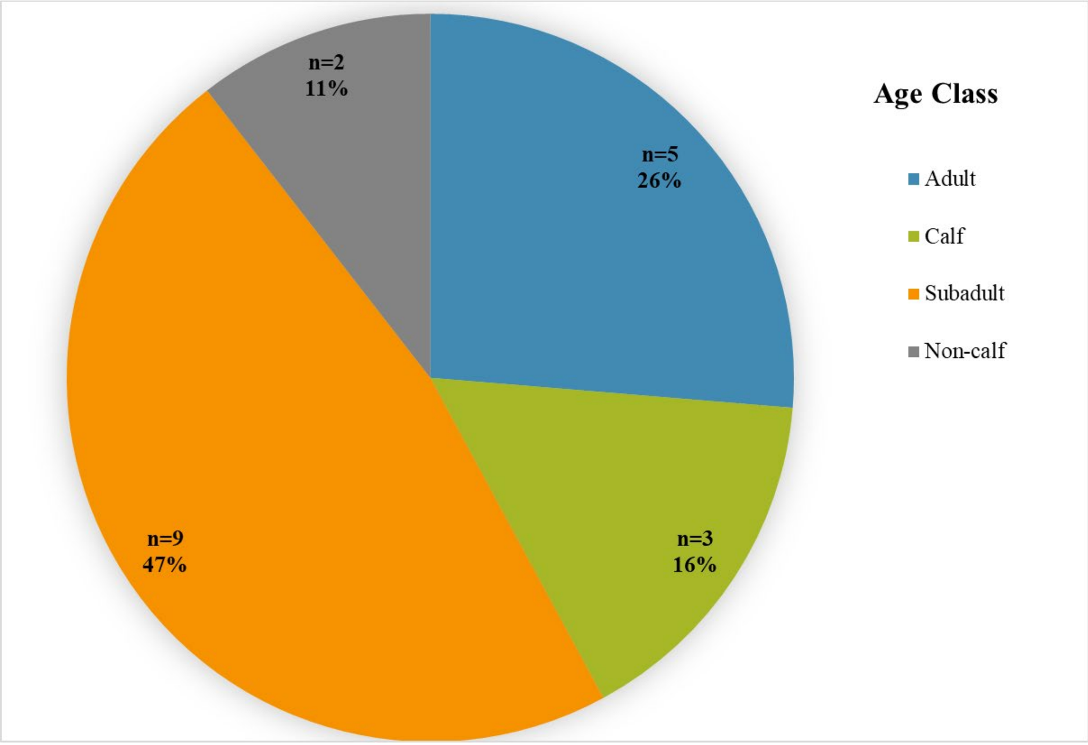


***Figure 21. Age class of entangled killer whales in Alaska (when known), 1991-2022 (n=19).***

In most Alaska cases (68%), the killer whale died because of the entanglement (**Figure 22**). In 19% of cases, live animals were partially or fully disentangled, and as discussed above, most of these cases resulted in a serious injury determination. These results are mostly due to the lethality of the entanglement mechanism. Trawl net associated entanglements represent 54% (n=20) of all Alaska reports, and 75% (n=15) of these resulted in death of the whale (**Figure 23**). Trawl nets are typically towed behind vessels for one or more hours; a killer whale that becomes trapped in the net usually dies before the fishers are aware of the entanglement. If a killer whale becomes caught or entangled in a trawl net, the only likely survivable scenario is if the animal enters the net during haul back or shortly before the net is recovered and is not physically crushed by the catch or net. Longline entanglements also result in low survival of the entangled killer whale; 80% (n=8) of reported longline entanglements (n=10) were fatal to the animal (**Figure 23**). Like trawl nets, longlines can soak for hours at a time, and if a whale becomes entangled in the line before haul back or before the near-surface gear recovery, it will likely die. Likewise, mortality is most likely before the animal is discovered and the fisher can attempt to release it. Gillnets, or other fishing operations that soak longer than killer whales can survive without air will also present higher risk to entangled animals. Mitigation measures such as checking gear regularly or not setting in an area where killer whales are present may reduce the risk of entanglement but are not always possible.

Other types of entangling materials such as pot gear, marine debris, and mooring gear may be lighter, and not represent an immediate threat to the animal's life, offering more opportunity for response and disentanglement by trained responders. However, the outcomes of entanglement cases where no response or intervention is possible are often unknown (**Figure 22**). The whale may be able to tow the entanglement, but without sophisticated tracking technology or continuous on-water monitoring, it is difficult to track and observe the entangled animal to know the outcome.

Ingestion of marine debris or fishing gear can kill animals, but it can be challenging to document sub-lethal injuries. If an animal ingests debris or fishing gear that breaks from its mooring, there may be no outward sign of an entanglement until the animal has already died. Again, prevention through proper gear retrieval, minimizing soaking times, or the cessation of fishing when killer whales are present may be the best strategy for mitigating these occurrences.

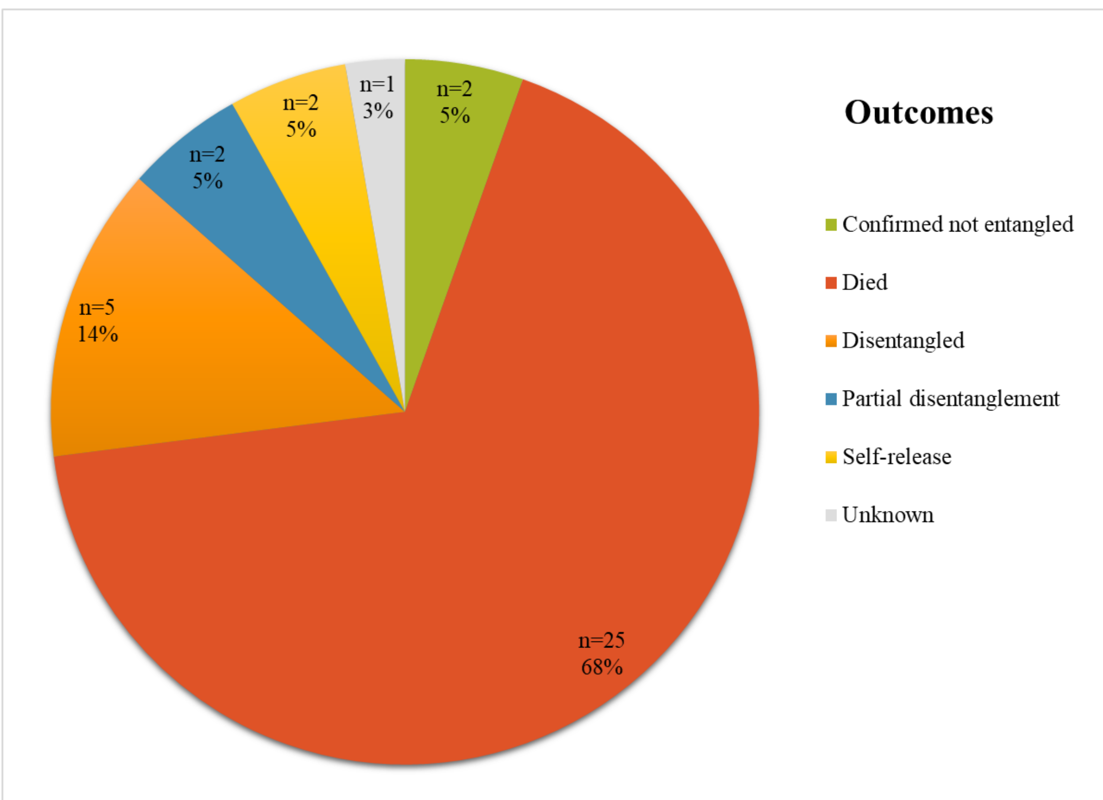


***Figure 22. Outcomes of entanglement events for killer whales in Alaska, 1991-2022 (N=37). The two "confirmed not entangled" cases were determined to be kelp.***

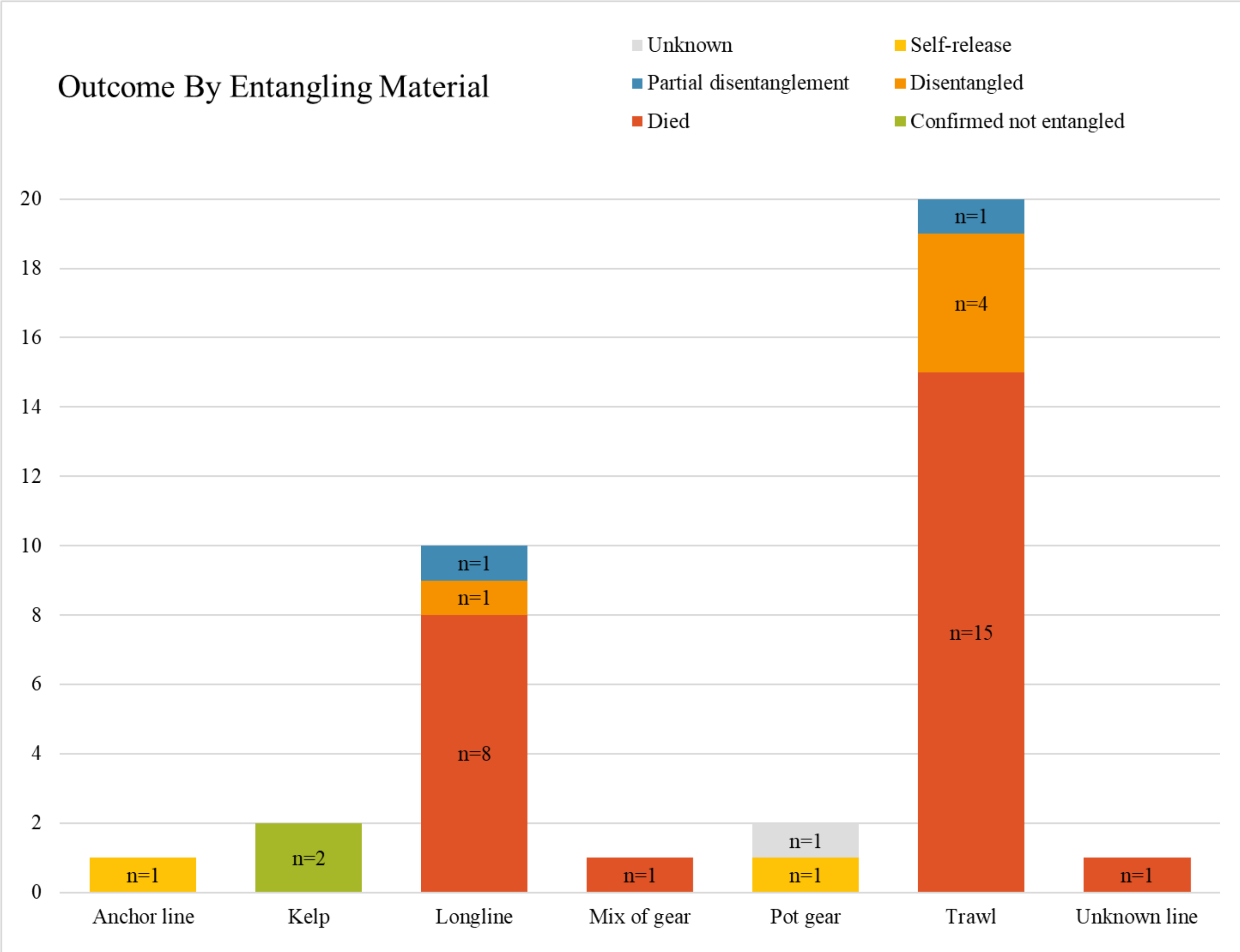

***Figure 23. Outcomes by entangling material. Bars represent total cases involving each gear type. Color corresponds to the outcome of the entanglement (N=37).***

# Possible Mitigation Measures

Several mitigation strategies have been considered for preventing or reducing killer whale interactions with fisheries. Fishing in areas that offer more room for both human fishers and killer whales can reduce negative interactions. In Norway, killer whales predate herring and have become entangled in purse seines targeting herring. These interactions increased when the herring fishery was in narrow fjords and were reduced during years where the fishery operated in wider fjords (Bjørge et al. 2023). In offshore environments, Alaska fishers sometimes move to avoid pods of depredating killer whales or wait until whales leave the fishing site (Peterson and

Carothers 2013). When whales cannot be avoided, other techniques to minimize depredation include using decoy sets or working in coordination with other boats to fish one set more quickly.

The efficacy of acoustic deterrents' (pingers) on killer whales has not been thoroughly studied. Studies measuring the effect of acoustic deterrents on depredation rates by other species of odontocetes on trawl net catches were inconclusive (Hamilton and Baker 2019, Bonizzoni et al. 2022), and in some cases odontocetes became attracted to the fishing activity by the sounds of the pingers (Fader, Elliott and Read 2021). Some fishers report that pingers do have limited success in deterring killer whales and are more effective than other types of deterrents (Peterson and Carothers 2013). For trawl net fishing, devices such as mesh or rope barriers across the net opening or internal escape hatches have been studied for use in reducing dolphin bycatch, with inconclusive results (Hamilton and Baker 2019).

In longline fisheries, "net sleeves" (devices that cover the fish during net hauling) have demonstrated some success in reducing depredation by killer whales (Hamer, Childerhouse and Gales 2012). Weak gear, such as hooks that straighten under the strain of a hooked marine mammal, are another longline technology that may allow a hooked marine mammal to self-release. However, the animal may still ingest gear, which is currently considered to be a serious injury for small cetaceans (Hamer, Childerhouse and Gales 2012, Hamilton and Baker 2019) (88 FR 7957, February 7, 2023). Additionally, weak hooks do not reduce depredation or damage to fishing gear and catch. Longline pots as a replacement for hook-and-line gear are another technique for reducing mammal depredation in the sablefish industry and are becoming more popular, particularly with the use of collapsible pots (Jenkins and Garrison 2013). However, anecdotes reported to NMFS suggest that some killer whales are learning to remove fish out of pots. The use of pingers, exclusion devices, escape hatches, net sleeves, and other methods to reduce killer whale depredation and bycatch requires more research and development. The effect of these measures on killer whale entanglements should be studied.

In cases where entanglements cannot be prevented, data-informed reporting requirements are of the utmost importance for stock management. Skin samples collected from dead entangled killer whales can be used for genetic analysis to determine stock, pod (for well-known groups), and sex. Perpendicular photographs of the dorsal fin and saddle patch from both sides can be used to identify individuals and may be a way to identify the stock/pod without genetic information. Likewise, targeted photographs of the entanglement and the whale help NMFS to understand the mechanisms of entanglements, understand risk factors for the species, and create summary reports such as this. Detailed descriptions regarding the entanglement, including the behavior of the animal before and after the entanglement event, details of disentanglements, descriptors of size, length, sex, markings, injuries, or any other details, greatly advances NMFS' understanding of killer whale entanglements.

The cases presented here represent the entanglement reports which were collected by NMFS through the three programs described above. Additional research could expand our understanding of killer whale behaviors and interactions with anthropogenic material. Suggestions and innovations by fishers to reduce killer whale gear interactions could be applied statewide. New sources of data will be especially important to our understanding of the extent of killer whale entanglements as fisheries evolve, mariculture becomes more prevalent, and killer whale populations and behaviors change over time. For more information regarding the MMAP, fisheries Observer Program, or Alaska Marine Mammal Stranding Network see NMFS technical resources or visit www.NOAA.gov (Freed 2022). Finally, it may be more likely for an observer, fisher, or member of the public to report entanglements that appear extremely detrimental to the animal or that result in mortality than threats that are perceived to be minor. Educating the public and professionals about the diverse scenarios that constitute entanglement can encourage reporting cases with low severity or positive outcomes and increase our understanding of the relative entanglement risks that killer whales face.

# Disentanglement Best Practices

NMFS conducts, authorizes, and oversees entanglement responses for all cetaceans in US waters, including killer whales. NMFS-sanctioned responses in Alaska are conducted under MMPA Section 109(h) or the MMHSRP permit (#24359 for 2023-2027). Commercial fishers who inadvertently entangle a killer whale in Alaska are authorized to conduct a response under the Good Samaritan exemption of the MMPA (MMPA Section 101(d)). Other members of the public are not authorized to disentangle or interact with an entangled marine mammal. Concerned citizens who witness an entangled marine mammal are encouraged to contact the Alaska NOAA Fisheries' marine mammal response hotline at 1-877-925-7773. In remote areas without phone service, the report should be relayed to the U.S. Coast Guard over VHF channel 16. The USCG will relay the report.

The MMHSRP recently completed a Programmatic Environmental Impact Statement (PEIS) for their ongoing response activities. The PEIS contains the Large Whale Entanglement Response (LWER) Best Practices (Appendix XIX in the PEIS) and Small Cetacean Entanglement Response Best Practices (Appendix XX in the PEIS), which provide guidelines for trained entanglement responders (NMFS 2022b). Responding to entanglements properly is crucial for both the welfare of the whales and the safety of responders. The Best Practices documents provide guidelines to help minimize risks and ensure the best possible outcomes for both cetaceans and responders.

Large Whale Entanglement Response Network members are authorized by NMFS to conduct response efforts for entangled large whales. In contrast, small cetacean entanglement response is less defined, and may be conducted under a MMHSRP's MMPA/ESA permit or under MMPA 109(h) (NMFS 2022b). Either way, a whale's size and unpredictable behavior, along with the challenges of dealing with the marine environment, make these operations inherently dangerous.

The entanglement response to killer whales, being the largest of the dolphins, requires both large whale and small cetacean response protocols which poses some unique challenges. Some lessons learned from the field are summarized below (Wilkinson 2020). The following should only be used as guidelines for trained and authorized responders.  Disentanglement efforts on killer whales by members of the general public are unauthorized and members of the general public should not attempt close approach or disentanglement of marine mammals.

Killer whales, due to their smaller size, are in danger of asphyxiation in less than an hour if the entanglement is complex enough to inhibit regular surfacings. Under these circumstances, response times for killer whales should be kept within one hour if possible and safe to do so. This is much shorter than the typical response times expected for large baleen whales.

Black line is particularly difficult to see on killer whales, so responders should take every measure to acquire as much information about the nature of the entanglement (i.e., conduct a thorough risk assessment) as possible before beginning a close approach. This might include a drone flyover, high-definition camera photos, and other forms of technology that can help identify the location of the line on the whale.

Killer whales are powerful animals with high endurance and can drag gear for many miles or hours. Satellite trackers applied to animals or gear should be considered for animals dragging gear to provide for response when conditions and resources allow. However, adding significant drag is a concern for killer whales, so low drag tagging technology should be used. Drone technology can also be used to better document and determine the entanglement configuration, which will reduce the number of close approaches to the animal. Killer whales' ability to learn human behavior may limit the number of attempts responders have to disentangle the whale before it alters its behavior. Their unpredictable responses should be taken into consideration when evaluating risk.

Responders may need to be in close proximity with entangled killer whales, and so should move slowly, methodically, and cautiously to avoid startling or disturbing the whale. Some of the larger grapples used in responses to large baleen whales may not be appropriate in killer whale responses. Smaller equipment, such as smaller grapples, may be more appropriate.

In publicized cases of killer whale entanglements, the public may become concerned and attempt unauthorized assistance. Consistent early communication of the response plan, reminders that human safety is paramount, and public notification that there are trained and authorized teams that are willing and able to respond (depending on the location of the entangled whale) can diminish public anxiety and expectations. Finally, veterinarians and experts in killer whale capture and husbandry should be consulted for health assessments, possible sedation, or temporary care for unusual cases (Wilkinson 2020).

# Conclusion

Killer whales are curious, intelligent, and powerful animals that have learned strategies to depredate human fish catches and may exhibit play or defensive behavior that includes intentionally interacting with lines in the water. Killer whales may interact with marine debris, vessel lines, or other human-introduced gear in their environment for many reasons that are difficult to prevent or anticipate. These behaviors put them at increased risk of entanglement in anthropogenic materials. Analysis of 37 reported killer whale entanglement reports in Alaska waters from 1991 to 2022 show that trawl and longline gear accounted for most reported incidents (54% and 27% of total reports, respectively). The outcome of the entanglements varied;

some whales were partially or fully disentangled (19%) or self-released (5%), while most (68%) died because of the entanglement. The outcome of 3% of cases was unknown and 5% were confirmed not to have been entangled. Most of the whales that were released alive were determined to have sustained serious injuries and were more likely than not to die of those injuries. Young whales appear to be at greater risk of entanglement (63%), possibly due to exhibiting risky behavior or less experience with interacting with anthropogenic materials. Finally, spring and summer were the seasons with the highest risk of entanglement, with 30% of cases occurring in July. It is not possible to draw definite conclusions about trends in occurrences over time because of the modifications to NMFS reporting programs in the past 30 years. The nature of these entanglements demonstrates the need for more research and development of killer whale depredation deterrents or other mitigation measures for commercial fisheries. In cases where live entangled killer whales are observed and a response is possible, responders are cautioned to consider how typical large whale response techniques can be adapted, and should implement a response plan that considers killer whales' unique behaviors and size. Having these plans and specialized tools in place in advance of an actual event will increase the likelihood of a safe and successful response effort by trained and authorized responders.

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# Appendix

***Killer whale entanglements in Alaska from 1991-2022, presented in reverse chronological order.***

***Subarea abbreviations: Bering Sea=BS, GOA=Gulf of Alaska, SCAK=Southcentral Alaska, SEAK=Southeast Alaska.***

***Report Type abbreviations: Marine Mammal Authorization Program=MMAP, AK Marine Mammal Stranding Network=AKMMSN, Observer Program=OP***

| Year | Case Number and Stock ID (superscript) | Report Type | Subarea | Type of Gear | Entanglement Outcome | Commercial Fishery |
|---|---|---|---|---|---|---|
| 2022 | 17 | MMAP, OP | BS | Trawl | Died | AK BSAI flatfish trawl |
| 2022 | 18 | MMAP, OP | BS | Trawl | Died | AK BSAI flatfish trawl |
| 2022 | 19 | MMAP, OP | BS | Longline | Died | AK BSAI Pacific cod longline |
| 2021 | 16 | MMAP, OP | BS | Trawl | Died | AK BSAI flatfish trawl |
| 2021 | 13 [3] | MMAP, AKMMSN | BS | Trawl | Died | AK BSAI pollock trawl |
| 2021 | 14 [3] | MMAP, OP | BS | Trawl | Died | AK BSAI flatfish trawl |
| 2021 | 15 [3] | MMAP, OP | BS | Trawl | Disentangled (Serious injury) | AK BSAI flatfish trawl |
| 2020 | 11 [3] | MMAP, OP | BS | Trawl | Died | AK BSAI flatfish trawl |
| 2020 | 12 [3] | MMAP, OP | BS | Trawl | Died | AK BSAI flatfish trawl |
| 2018 | 6 | AKMMSN | SEAK | Pot gear | Self-release | Non-Commercial Fishery |
| 2018 | 37 [1] | MMAP, OP | BS | Trawl | Died | AK BSAI flatfish trawl |
| 2017 | 4 | AKMMSN | SEAK | Anchor line | Unknown | Non-fishery |
| 2017 | 7 | AKMMSN | SCAK | Kelp | Confirmed not entangled | Non-Fishery |
| 2016 | 3 | AKMMSN | SEAK | Pot gear | Unknown (Serious injury) | Unknown |
| 2016 | 10 [3] | MMAP, OP | BS | Longline | Died | AK BSAI Pacific cod longline |
| 2015 | 5 | AKMMSN | SEAK | Kelp | Confirmed not entangled | Non-fishery |
| 2015 | 9 | MMAP, OP | BS | Longline | Partial disentanglement (Serious injury) | AK BSAI Greenland turbot longline |
| 2013 | 35 | OP | BS | Trawl | Partial disentanglement (Serious injury) | AK BSAI flatfish trawl |

| *Year* | *Case Number and Stock ID (superscript)* | *Report Type* | *Subarea* | *Type of Gear* | *Entanglement Outcome* | *Commercial Fishery* |
|---|---|---|---|---|---|---|
| *2013* | *36* | *OP* | *BS* | *Trawl* | *Disentangled (Serious injury)* | *AK BSAI flatfish trawl* |
| *2012* | *32* | *OP* | *BS* | *Longline* | *Disentangled (Non-serious injury)* | *AK BSAI Pacific cod longline* |
| *2012* | *33* | *OP* | *BS* | *Longline* | *Died* | *AK BSAI Pacific cod longline* |
| *2012* | *34* | *OP* | *BS* | *Trawl* | *Disentangled (Serious injury)* | *AK BSAI flatfish trawl* |
| *2007* | *8* | *MMAP* | *GOA* | *Longline* | *Died* | *AK BSAI sablefish longline* |
| *2007* | *31* [3] | *OP* | *BS* | *Longline* | *Died* | *AK BSAI Greenland Turbot Longline Fishery* |
| *2005* | *2* [3] | *AKMMSN* | *SEAK* | *Mix of salmon and halibut fishing gear* | *Died* | *Unknown* |
| *2004* | *30* | *OP* | *BS* | *Trawl* | *Disentangled (Serious injury)* | *AK BSAI flatfish trawl* |
| *2003* | *28* [3] | *OP* | *BS* | *Longline* | *Died* | *AK BSAI Pacific cod longline* |
| *2003* | *29* [1] | *OP* | *BS* | *Trawl* | *Died* | *AK BSAI pollock trawl* |
| *2002* | *27* [1] | *OP* | *BS* | *Trawl* | *Died* | *AK BSAI pollock trawl* |
| *1999* | *25* | *OP* | *BS* | *Longline* | *Died* | *AK BSAI Greenland Turbot Longline Fishery* |
| *1999* | *26* | *OP* | *BS* | *Trawl* | *Died* | *AK BSAI pollock trawl* |
| *1998* | *1* | *AKMMSN* | *BS* | *Unknown line* | *Died* | *Unknown* |
| *1997* | *24* | *OP* | *BS* | *Trawl* | *Died* | *AK BSAI pollock trawl* |
| *1995* | *23* | *OP* | *BS* | *Longline* | *Died* | *AK BSAI Pacific cod longline* |
| *1993* | *22* | *OP* | *BS* | *Trawl* | *Died* | *AK BSAI flatfish trawl* |
| *1992* | *21* | *OP* | *BS* | *Trawl* | *Died* | *AK BSAI pollock trawl* |
| *1991* | *20* | *OP* | *BS* | *Trawl* | *Died* | *AK BSAI pollock trawl* |

[1] ***Eastern North Pacific Gulf of Alaska, Aleutian Islands, and Bering Sea Transient Stock***
[2] ***West Coast Transient Stock***
[3] ***Eastern North Pacific Alaska Resident Stock***
[4] ***Eastern North Pacific Northern Resident Stock***

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