Alaska Trawl Fisheries: Potential Interactions with North Pacific Albatrosses

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Contents

List of Tables (insert)

List of Figures and Diagrams (insert)

Acronyms

AFSC	Alaska Fisheries Science Center
AI	Aleutian Islands
BFAL	Black-footed albatross
BiOp	Biological Opinion
BS	Bering Sea
CAS	Alaska Region Catch Accounting System
CDQ	Community Development Quota
CP	Catcher-processing vessel
CV-S	Catcher vessel delivering to shore-based plants
CV-M	Catcher vessels delivering to motherships
EFH	Essential Fish Habitat
ESA	Endangered Species Act
FMA	Fishery Monitoring and Analysis Division
FMP	Fishery Management Plan
GOA	Gulf of Alaska
IPHC	International Pacific Halibut Commission
LAAL	Laysan albatross
M	Motherships
NMFS	NOAA Fisheries National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPGOP	North Pacific Groundfish Observer Program
USFWS	United States Fish and Wildlife Service
SSL	Steller sea lion
STAL	Short-tailed albatross
TAC	Total allowable catch
WSG	Washington Sea Grant

Executive Summary

Studies of trawl fisheries in other parts of the world indicate that seabird collisions with trawl cables (cable strikes) can result in significant mortality of large winged seabirds such as albatrosses. As a consequence of excessive seabird mortalities, trawl third wires have been prohibited in several southern hemisphere fisheries starting in 1991. More recently, collisions with warp cables (warp strikes) have been shown to kill albatrosses in large numbers in a few southern hemisphere fisheries. These observations have led to questions regarding the extent to which seabird cable strikes may be a conservation issue in Alaska trawl fisheries. The short-tailed albatross biological opinion (STAL BiOp) was extended to include Alaska trawl fisheries in 2003 based on reports from other fisheries and reports of seabird mortalities, including albatrosses, on third-wire cables in Alaska. The STAL BiOp sets an incidental take limit of two STAL over a five-year period and requires the National Marine Fisheries Service (NMFS) to submit a summary report estimating total third-wire effort in Alaska groundfish fisheries.

One objective of this report was to provide NMFS with estimates of warp and third-wire effort by target fishery, large geographic region and vessel type for Alaska trawl fisheries to fulfill their required reporting to the U.S. Fish and Wildlife Service (USFWS). A second objective was to provide information that will guide future investigations of the extent and significance of seabird cable strikes in the Alaska fisheries and inform the development of mitigation technologies and practices, should they be necessary. This latter objective prompted the addition of the following elements in this report:

- A description of Alaska's trawl fleets;
- Information regarding third-wire use in Alaska trawl fisheries;
- Albatross distribution and overlap with trawl fishing effort and a brief review of documented seabird-fishery interactions; and
- Recommended priority areas for future seabird interaction investigations.

We combined data collected by the North Pacific Groundfish Observer Program (NPGOP), NMFS Alaska Region's Catch Accounting System and an industry questionnaire to estimate warp and third-wire effort (hours). The estimates of effort in this report are minimum values for the tow period only. To determine albatross overlap with trawl fisheries effort when most of the seabird observations were collected (summer 2004 and 2005), we also used NMFS seabird sightings collected during stock assessment surveys, opportunistic short-tailed albatross sightings maintained by the USFWS, and satellite tracking data.

During 2003-2005, 192 unique trawl vessels (on average) fished in Alaska and included 40 catcher-processing vessels, 149 catcher vessels delivering to shore-based plants and 20 catcher vessels delivering to motherships. A few individual vessels participated in multiple sectors.

Annual warp effort ranged from 359,550 to 378,214 hours and varied by target fishery – pollock (47%), cod (22%), flatfish (25%), Atka mackerel (2%) and rockfish (3%) – and large geographic region – Bering Sea (BS; 80%), Gulf of Alaska (GOA; 15%) and Aleutian Islands (AI; 5%). Warp effort also varied spatially and temporally for each fishery.

Third-wire systems provide an uninterrupted signal, allow a wider array of information to be transmitted and provide a better view of the net. For a variety of reasons, third-wire systems are common in the pelagic pollock fishery and less common in the other fisheries. Between 2003 and 2005, estimated annual third-wire effort ranged from 90,161 to 96,579 hours. Most of that effort occurred in the pollock fishery (81%), followed by flatfish (11%) and cod (7%), and in the Bering Sea (93% of total).

Although the vast majority of warp and third-wire effort during 2003-2005 occurred in three fisheries - pollock, cod and flatfish - overlap with albatross sighted during the primarily summer NMFS surveys was minimal, except at the BS shelf break in 2004, when it was moderate to high. The Atka mackerel and rockfish fisheries, on the other hand, had a relatively high overlap, given the smaller proportion of effort during the albatross non-breeding season, when albatrosses are at peak abundance in Alaska waters. It is important to note that seabird data were limited or unavailable for some high-effort months in the pollock (February-March, September-October), cod (February), and Atka mackerel (September-October) fisheries, and seabird surveys did not cover the same territory in both years.

Overlap of seabirds with fishing effort does not necessarily mean that seabirds, albatrosses in particular, are interacting with trawl gear. Nor can we rule out the possibility that high-effort fisheries with minimal albatross overlap could have adverse effects, given their scale. Much more information is required regarding the temporal and spatial distribution of all albatrosses and these fisheries. Quantifying the collision and mortality rates of albatrosses interacting with trawl cables (warp or third wire) with attention to vessel type and cable aerial extent in fisheries with high albatross overlap is essential as a first step.

Alaska fisheries are not static, and cable effort is influenced by a multitude of factors. Proposed management measures have the potential to prompt changes to several fisheries in the near future, which are very likely to affect both the temporal and spatial distributions of trawl effort.

Based on this analysis, we recommend that future efforts by NMFS to determine the extent of overlap with albatross and interactions with trawl gear in the federal fisheries off Alaska focus on rockfish in the GOA, Atka mackerel in the BSAI from May to October, and possibly cod in the AI in winter, due to previously observed interactions in this fishery. If few interactions are found in fisheries with consistently high albatross overlap, we propose it is fair to conclude that Alaska trawl cables pose no significant risk to albatrosses. If albatross interaction rates and mortalities are high in these fisheries, then mitigation development and testing should be staged in fisheries with the highest interaction rate, and high-effort, minimal-overlap fisheries should be revisited to determine the need for mitigation.

Introduction

Seabird mortality in fisheries is recognized as a global marine conservation issue (Brothers et al. 1999, FAO 1999). Seabirds are attracted to fishing vessels due to the discharge of whole fish and offal. Once in the vicinity of a trawl vessel, seabird mortality can occur due to collisions with cables (cable strikes) running from the vessel to the net (warp cables) and/or net monitoring devices (third wire, netsonde and paravane) and via entanglement in the net itself (Weimerskirch et al. 2000, Sullivan et al. 2006). Cable strikes can occur with birds on the water or in the air when they are in close proximity to both cables and the offal discharge stream. Cable strikes may increase as a function of cable visibility (e.g., diameter, material), aerial extent of the cable (i.e., larger aerial extent may pose a higher risk), location of fishery discharge relative to the cable entry point into the water, type of discharge (e.g., whole fish versus macerated) and the number and extent of vessel turns, which can affect the location of the cable relative to discharge stream and seabirds.

Due to substantial albatross mortality resulting from wire strikes, third-wire cables were prohibited in several southern hemisphere fisheries beginning in the early 1990's (Bartle 1991, Weimerskirch et al. 2000). No attempts were made to mitigate these interactions with modified gear or fishing practices. More recently, warp strikes were shown to kill albatrosses in large numbers in a number of southern hemisphere trawl fisheries (New Zealand Ministry of Fisheries 2005, CCAMLR 2006a, Sullivan et al. 2006). Large winged birds such as albatrosses and giant petrels are most susceptible to mortalities from trawl-cable strikes (CCAMLR 2006a).

Fishery observers are not required to collect data on seabird interactions with trawl cables in Alaska trawl fisheries; however, qualitative reports by fishery observers documented Laysan albatross (*Phoebastria immutabilis*; LAAL) mortalities resulting from third-wire strikes (Labunski and Kuletz 2004). LAAL share a common distribution with short-tailed albatross (*P. albatrus*; STAL), a congeneric species listed as endangered under the U.S. Endangered Species Act (ESA). These fatal interactions, coupled with reports of albatross mortalities from interactions with trawl cables in southern hemisphere fisheries, suggested that the endangered STAL may interact with trawl cables in the Alaska groundfish fisheries. Based on this information and information about the groundfish longline fishery, the USFWS determined in the biological opinion (BiOp) that both the groundfish longline and trawl fisheries are likely to adversely affect the STAL due to this species' distribution and foraging ecology and its association with fishing vessels (USFWS 2003). The STAL BiOp included an incidental take statement authorizing the expected take of two short-tailed albatrosses in Alaska's trawl fisheries over the time period in which this biological opinion remains in effect (approximately five years). No STAL takes were documented in the groundfish trawl fishery since the inception of the domestic observer program in 1990; however, we note that fishery observers are not required to systematically monitor seabird-trawl cable interactions as part of their prescribed duties. In order for the fishery to be exempt from the prohibitions of endangered species take (Section 9 of the ESA), NMFS must also comply with several non-discretionary terms and conditions, which implement the reasonable and prudent measures described in the STAL BiOp. These conditions require NMFS to submit a report to USFWS estimating total third-wire effort in Alaska groundfish trawl fisheries and an explanation of why third-wire cables are standard gear in some of the North Pacific trawl fisheries, in light of third-wire bans in some southern hemisphere fisheries.

Differences between the fisheries and seabirds in the northern hemisphere and the southern hemisphere suggest that the extent of lethal cable strikes could be quite different between the two. First, the seabird communities and species are very different. For example, only three of 22 albatross species occur in the North Pacific, and albatross numbers are half that of the southern hemisphere. Second, the conservation imperative in the North Pacific is less clear-cut. Most of Alaska's resident seabird populations appear to be more strongly influenced by climate-related events than fisheries events (Dragoo et al. 2004, Boldt 2006). Black-footed (*P. nigripes*; BFAL) and Laysan albatrosses are listed by the World Conservation Union as endangered and threatened, respectively. Neither species is currently listed under ESA, although the USFWS recently initiated a full 12-month status review in response to a petition to list BFAL under ESA (USFWS 2007). A recent assessment of these species suggested conflicting population trends depending on the benchmark year selected for the evaluation (Naughton et al. 2007).

Finally, fishery discard practices also differ. In Alaska, vessels processing fish at sea are required to macerate seafood processing waste[1] and bycatch of non-prohibited species into pieces no larger than one-half inch in size (Environmental Protection Agency, Clean Water Act National Pollutant Discharge Elimination System Permit No. AK-B52-0000). Catcher vessels (no processing), on the other hand, discard whole fish. Timing of discards is not regulated. In the southern hemisphere, on the other hand, mincing is not required and discarding of whole fish or offal during setting and hauling of trawl gear is banned or strongly discouraged in some fisheries (CCAMLR 2006b).

One objective of this report was to provide NMFS with estimates of warp and third-wire effort by target fishery, large geographic region, and vessel type in Alaska trawl fisheries to fulfill their required reporting to the USFWS. A second objective was to provide information that will guide future investigations of the extent and significance of seabird cable strikes in the Alaska fisheries and inform the development of mitigation technologies and practices, should they be necessary. This latter objective prompted the addition of the following elements in this report:

- A description of Alaska's trawl fleets;
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- Recommend priority areas for future seabird interaction investigations.

[1] Seafood-processing wastewater and wastes include the waste fluids, heads, organs, flesh, fins, bones, skin, chitinous shells, and stickwater produced by the conversion of aquatic animals from a raw form to a marketable form.

Methods

Fishery Description

Alaska trawl fisheries target a range of species including walleye pollock (*Theragra chalcogramma*), Pacific cod (*Gadus macrocephalus*), Atka mackerel (*Pleurogrammus monopterygius*), sablefish (*Anoplopoma fimbria*), skates (*Raja* and *Bathyraja* spp.), and several flatfish (Pleuronectidae) and rockfish (Sebastidae) species. Alaska trawl fisheries are managed under a quota system (total allowable catch-TAC). Each species is allocated a quota by region, often with further allocations based on different gear and vessel types or within smaller management areas. Some fisheries are open access, whereas others are controlled through vessel cooperatives or community development quotas (CDQs). In addition to catch quotas, there is a suite of complex regulations in place pertaining to numerous conservation measures.

Alaska trawl fisheries extend across three large geographic regions: the Bering Sea (BS), Aleutian Islands (AI) and Gulf of Alaska (GOA). The BS is one of the most productive large marine ecosystems in the world (PICES 2004). It is semi-enclosed and contains a large continental shelf (<200m depth) which is more than 500 kilometers wide (Loughlin and Ohtani 1999). Currently, the overall catch limit in the BS is two million metric tons[2], although allowable catch is higher (3.04 million metric tons). Quotas for each species are adjusted annually to accommodate the overall limit. Pollock has the highest catch allocation and is exclusively a pelagic fishery in the BS. The AI management area extends from 170 degrees west longitude west to Russian waters beyond Attu Island and is characterized by a very narrow shelf and strong currents. All fishing in the AI is spatially and temporally restricted by Steller sea lion (SSL, *Eumetopias jubatus,* an endangered species*)* conservation measures and essential fish habitat (EFH) protection measures. Atka mackerel is the primary trawl target fishery in the AI. The GOA extends from southeast Alaska to 170 degrees west longitude. The GOA has a narrow shelf (370,000 km^2) ranging from five to 200 kilometers in width. The GOA is also highly productive, although the TAC is an order of magnitude lower than the BS. Trawl fisheries for pollock, cod, flatfish and rockfish are all important in the GOA, depending on the criteria used to determine importance.

In 2005, Alaska trawl fisheries were the largest fisheries in the United States by weight (2.29 million metric tons) and accounted for nearly 20 percent of U.S. landing ex-vessel value ($541 million; gross product or processed value $849.3 million; NMFS 2007, Hiatt 2007). Total economic impact of these fisheries is likely to be well over $1 billion, considering standard fisheries economic multipliers (Seung and Waters 2006).

Several trawl vessel types are used in Alaska. Catcher processing vessels (CPs) catch and process fish into frozen products on board. CPs range from 106 to more than 300 feet long. Catcher vessels (CVs) catch fish and either deliver whole codends to motherships (CV-M) or store fish on ice or in refrigerated salt water for delivery to shore-based processing plants (CV-S). CVs range from 58 to 200 feet long. Motherships (M) are mobile processing plants that receive codends from CVs at sea. Effort for these CVs is discussed in terms of CV-M for the remainder of this report. A small subset of CPs, two or three each year, also functioned on a part-time basis as motherships, although the bulk of mothership deliveries were to three vessels that acted exclusively as motherships (98% of delivered weight).

Gear Description/Terminology

In general, trawling involves towing a cone-shaped net to catch fish or shellfish[3]. As the net is towed, sea water is filtered, and catch accumulates in the terminal end of the net, referred to as the codend (Figure 1). In most cases, trawl doors keep nets open horizontally, whereas floats and weights keep the nets open vertically. The trawls are towed either in contact with the bottom (demersal) or off bottom (mid-water or pelagic). The most typical type of trawl in Alaska is the otter trawl, in which two warp cables connect the vessel to otter boards or trawl doors (Figure 1).[4] Warps have a short aerial extent (i.e., enter water within 70 feet of the stern) although this varies by block height, fishing depth, and towing speed. Winches installed on deck store the warps and control the net's depth. The warp block, a large pulley typically located at the vessel's stern, supports the warp cable between the winch and the water (Appendix A, Diagram #2).

Nets can be monitored for depth, shape of opening, amount of catch, etc., using one or a combination of three techniques:

1. Wireless, hull-mounted acoustic systems communicate via sound waves with an array of devices attached to the net;
2. Paravane systems communicate using sound waves similar to the hull-mounted system, except the acoustic receiver (hydrophone) is towed near the surface by a cable that remains relatively near the vessel (<20 ft); or
3. Direct-link systems use a third wire cable to communicate with sonar devices attached to the net.

The fishing industry considers third-wire systems more advantageous than wireless systems because they provide an uninterrupted signal (including during course changes), allow a wider array of information to be transmitted and will more easily accommodate future technological improvements to net monitoring systems that may require higher data transmission capability (E. Richardson, pers. com.; see page 33 for further discussion). The third wire, which has a longer aerial extent (>100 feet from stern) and is less visible than the warps, may pose a greater risk to seabirds than warps.

One case of seabird interactions with a paravane system used in the Atka mackerel fishery in 1995 was reported to NOAA by a seabird scientist (Dr. Ian Jones, pers comm). Extensive cable strikes, up to one per minute, of both Northern Fulmars (*Fulmars glacialis)* and LAAL were reported, strongly suggesting that a paravane deployed in proximity to the offal discharge plume can lead to fatal interactions with seabirds.

[2] Harvest specifications: *http://fakr.noaa.gov/sustainablefisheries/2005hrvstspecs.htm*

[3] In Alaska, trawl gear is only used to harvest groundfish species (not shellfish).

[4] For more information on gear descriptions, see FAO. 1990. Definition and classification of fishing gear categories. FAO Fisheries Technical Paper 222 Rev. 1, Rome. *http://www.fao.org/fi/website/FIRetrieveAction.do?dom=ontology&xml=sectionM.xml*

Another fishing practice that plays a role in seabird interactions with third wires is shortwiring. Shortwiring occurs when a codend is brought from fishing depth to near the surface but is not hauled on board due to limited hold space. Pollock catcher-processors shortwire until storage is available for more fish. Shortwiring may affect seabird interactions in two ways: the aerial extent of the third wire is increased, potentially increasing bird interactions, but the warps are retrieved or held slightly below the sea surface leaving a short length of warp cable between the doors and the vessel, eliminating or reducing potential seabird interactions with the trawl warps.

The trawl process without shortwiring can be broken down into three discrete time periods, defined as follows:

1. Set – time codend leaves vessel to time net reaches fishing depth (gear deployment; ranges from 0.25-1 hour);
2. Tow – time net is at fishing depth (ranges from 0.25 to >12 hours); and
3. Haul – time net leaves fishing depth to time codend is on deck (gear retrieval; ranges from 0.25-1 hour).

When shortwiring, the haul is broken into two stages:

1. Shortwiring – time from when the net leaves fishing depth and the trawl doors are held at or above the surface at the stern; and
2. Haul – time from when the doors are racked until the codend is on deck.

Towing speed varies among trawl type and target species, ranging from one to seven knots, although three to five knots is most common.

Data Sources

The data used to characterize Alaska's trawl fisheries came from three sources: the North Pacific Groundfish Observer Program (NPGOP), Fisheries Monitoring and Analysis Division, Alaska Fisheries Science Center (AFSC), NMFS; NMFS Alaska Region Catch Accounting System (CAS); and a voluntary industry questionnaire. The data used to determine albatross overlap with trawl fisheries effort came from three separate sources: the Resource Ecology and Fisheries Management, AFSC seabird sightings collected during fish stock assessment surveys; STAL opportunistic sightings; and satellite tracking data.

Fishery Observer Data: Fishery observer requirements for the Alaska trawl fleet vary by vessel size[5]:

- ***100 percent coverage:*** vessels equal to or greater than 125 feet length overall (LOA) must carry one observer for all fishing days. Some fisheries (CDQ and BS pollock catcher processors) require two observers at all times which allows for a higher rate of biological sampling.
- ***30 percent coverage:*** vessels between 60 feet and 125 feet must carry one observer for 30 percent of their fishing days per quarter.
- ***0 percent coverage:*** vessels less than 60 feet are not required to carry fishery observers.

While onboard, NPGOP observers collected setting and hauling positions, tow duration, depth, and estimated total catch for each haul, either independently or from the fishing logbook. Hauling position was used for maps and assignment of NMFS fishery management areas. Tow duration was defined as the tow period above. Hauls were randomly selected for species composition sampling (i.e., how much of each species was caught) or biological specimen sampling (age structures; AFSC 2007). The NPGOP database provided information on each observed haul. Effort from both CDQ and non-CDQ were included. Fishery observers are not specifically tasked with collecting data on seabird interactions with trawl cables (AFSC 2007).

Catch Accounting System Data: We used the CAS data only to extract target fishery assignments for each observed haul. The CAS provides either total catch (CP, CV-M) or delivery weight (CV-S) data for all vessels by week, NMFS management area, vessel type and target fishery. Target species in the CAS database was assigned based on the species or species group with the highest catch weight for each week and area combination. The CAS decision rules for assigning target has the potential to affect estimates of effort by fishery. A vessel might have participated in more than one fishery in a given week and area. If the vessel only had 30 percent monitoring, the effort may be extrapolated to the wrong fishery. For the purpose of this report, the CAS target fishery assignments were collapsed as follows:

1. Pollock – combined demersal and pelagic trawl gear types into one category;
2. Cod – no change to CAS assignment;
3. Flatfish – combined deep water, shallow water and other flatfish, flathead sole, rock sole, turbot, kamchatka/arrowtooth flounder complex, rex sole, and yellowfin sole into one category;
4. Atka mackerel – no change to CAS assignment;
5. Rockfish – no change to CAS assignment; and
6. Other – combined sablefish and other into one category.

*Trawl Industry Questionnaire Data***:** Several fishing industry associations and individuals assisted with the development of a Washington Sea Grant (WSG) questionnaire (Appendix A). In order to minimize response time, we did not directly contact all trawl permit holders. Rather, industry association leaders and individual fishers facilitated obtaining responses from vessel operators. Response rates varied by vessel type and region. Our highest response was from the CPs: 73 percent of the vessels completed full questionnaire and another 12 percent responded to the use of third-wire section only. Our weakest response was from the CV-M (5%) and BS CV-S (12%). There was some vessel overlap among the regions, but when one examined CV-S in the AI and GOA, there was a response rate of 33 percent and 50 percent, respectively.

The questionnaire was primarily designed to determine which vessels utilized third wires in each fishery and the frequency of their use. We also asked about the aerial extent of the cables and frequency of vessel turns due to the potential for higher seabird interactions at longer aerial extents and during turns as the cable sweeps a wider area astern. Vessel turns were defined as a change of course exceed-

[5] Two amendments to Fishery Management Plans (FMP) that will increase future observer coverage requirements: Amendment 80, BSAI FMP, non-pollock trawl CP requirements (http://www.fakr.noaa.gov/analyses/amd80/amd80bsai.pdf) and Amendment 68, GOA FMP, Central GOA rockfish fishery *(http://www.fakr.noaa.gov/analyses/amd68/goa86frfa.pdf)*.

ing 45 degrees.

Seabird Sightings – NMFS Stock Assessment Surveys: We summarized albatross distribution data collected by the NMFS Alaska Fisheries Science Center during trawl and acoustic stock assessment surveys in 2004 and 2005. NMFS stock assessment surveys occurred over the Bering Sea continental shelf in both years, along the BS shelf break in 2005, in the GOA in 2004 and in the eastern part of the AI in 2005. We limited our overlap analysis to the observations occurring from June through August (91% of all observations) because these months had the best spatial coverage and highest sample sizes compared to other months. The sighting protocol, developed in collaboration with WSG, called for a point count of all seabirds within a standardized 50-meter hemisphere, either astern, port or starboard, near to or at the end of each trawl.

STAL Opportunistic Sightings: The USFWS requests all mariners to report sightings of STAL. Historic sighting data (through 2004) are stored in the North Pacific Pelagic Seabird Database (NPPSD; *http://www.absc.usgs.gov/research/NPPSD/index.htm*). Raw data for 2005 sightings from fishers and research cruises were obtained directly from the USFWS Endangered Species Division. Note that 2005 opportunistic sightings data do not include sightings from the fisheries observers and therefore was incomplete.

Satellite Tracking: One STAL, seven BFAL and nine LAAL were captured and satellite tagged in Seguam Pass in 2005 to determine their post-breeding distribution (Balogh and Suryan 2005; *http://www.wfu.edu/biology/albatross/shorttail/shorttail2.htm*). Data on the distribution of satellite-tagged albatrosses were provided directly by R. Suryan and G. Balogh.

Estimation of Cable Effort by Target Fishery

Effort, in terms of deployed cable hours, is the primary unit of interest when relating trawl fisheries to potential seabird interactions. This analysis estimates cable effort for the tow period; detailed data are not available for the other three periods. We assumed that the tow period recorded by fishery observers was accurate.[6]

Estimating total warp and third-wire effort during the tow period was a multi-step process which included: estimating missing tow duration data on observed vessels, estimating observed warp and third-wire effort, extrapolating warp and third-wire effort for the unobserved portion for 30 percent coverage vessels, and combining the observed warp and third-wire estimates with the extrapolated portion to estimate the total cable effort.

Step 1 – Estimating missing tow durations on observed vessels: Fishery observers reported that tow durations were compromised on 2.4 percent of all hauls during 2003-05. The NPGOP does not provide detailed information regarding why a tow duration is excluded for a given haul. This phenomenon may occur when CP vessels shortwire and when CV-M deliver to motherships. Some target fishery-year combinations had much higher rates of missing tow duration data (over 10%; Table 1) than expected, given the aforementioned reasons. These included Atka mackerel in 2003 and 2004 and rockfish in 2003. We used a linear mixed effects (LME) model (Pinheiro and Bates 2000) to predict missing tow durations. The final LME used a cubed root transformation of the response variable (tow duration), included six fixed effects (total catch weight, CAS-defined target fishery, year, month, NMFS management area and vessel type), and two random effects (target fishery nested within unique vessel). In general, the model predictions tended to underestimate actual fishing duration (Appendix B).

Table 1. Percent of hauls with missing tow duration in NPGOP data (Performance code=9) by year and target fishery.

	2003	2004	2005
Pollock	1.3%	1.0%	1.9%
Cod	2.1%	3.9%	3.1%
Flatfish	2.7%	2.0%	1.1%
Atka mackerel	**10.1%**	**20.7%**	4.7%
Rockfish	**10.9%**	2.0%	4.9%
Total	2.5%	2.6%	2.1%

[6] However, our experience in the BS pollock CP fishery indicated that captains and observers included the shortwire period in the tow period on occasion. For instance, in the WSG 2005 Bering Sea pollock seabird mitigation study on two vessels, the average difference per haul between the NPGOP tow duration and our independently collected tow duration was 1.4 hours for hauls that were shortwired (n=64).

Step 2 – Estimating observed warp and third-wire effort: Warp effort was estimated by doubling observed tow duration to account for both warps. Third-wire effort was estimated by multiplying tow duration by the percentage of time a vessel used a third wire for each fishery. For example, if a vessel used a third wire in the cod fishery about 20 percent of the time, that vessel's tow durations in the cod fishery were multiplied by 0.2. If no information was provided in the industry questionnaire regarding the percent of third-wire use, we assumed third-wire effort to be zero. Thus, it is highly likely third-wire effort is underestimated, but given data limitations, there is currently no way to estimate by how much.

Step 3 – Extrapolating warp and third-wire effort for the unobserved portion of 30 percent coverage vessels: The sum of observed warp and third-wire effort for 30 percent coverage vessels was divided by 0.3. This method assumes 30 percent coverage occurred across all combinations of target, large area and vessel type.

Step 4 – Calculating total warp and third-wire effort: We combined the sum of estimated warp and third-wire effort from 100 percent coverage vessels (step 2) with the sum of extrapolated effort from the 30 percent coverage vessels (step 3) to obtain total warp and third-wire effort. Vessels less than 60 feet were excluded from this analysis, as they harvest less than one percent of the overall groundfish catch (Table 2).

All figures with maps display observed warp or third-wire effort only. It would be inappropriate to extrapolate unobserved effort on the smaller spatial scale (40x40 km), as very little information was available for fishing times when vessels did not carry observers. We assume the observed effort was representative for the purpose of getting a general idea of where warp and third-wire effort occur spatially.

Determining Albatross-Fishery Overlap

We caution that the seabird distribution data from each source has strengths and weaknesses. For instance, the majority of STAL opportunistic sightings were collected from fishing vessels; therefore, these sightings are biased toward fishing areas. In addition, there is no measure of effort for opportunistic sightings (i.e., only positive sightings recorded). The data collected from stock assessment surveys are limited spatially and temporally and covered different regions from year to year. However, these data include effort ('zero' sightings), and therefore provide a more accurate representation of distributions. Satellite tracking data are limited because few birds were tracked (< 20 individuals) and transmitter batteries yield data for a maximum of 3 months; consequently, these data may not be representative of the entire STAL population at-sea distribution.

Given the caveats above and limited spatial and temporal coverage of sightings and satellite data, we have qualitatively defined overlap as when there is a positive observation (from any of the three data sources) in an observed fishing area (40x40 km grid of effort) during the June through August time period. No overlap is defined as zero observations. Minimal overlap is defined as one to 10 positive observations, moderate overlap is 11 to 49, and high overlap is 50 or more positive observations. Our ranking does not account for the magnitude of any observation, and categorical breaks are somewhat arbitrary but useful.

Table 2. Percent catch (landed weight; CAS data) by year and observer coverage level.

Coverage Level	2003	2004	2005
0%	0.8%	1.0%	1.3%
30%	23.5%	23.8%	23.2%
100%	75.6%	75.2%	75.5%
Total	100%	100%	100%

Results

Trawl Fleet Description and Cable Effort Estimates

The Alaska Trawl Fleet Overall

The number and types of vessels fishing in each region was consistent across years with two exceptions – the number of AI and GOA catcher vessels decreased by 13. Consequently, the total number of active vessels decreased from 200 to 187 vessels (Table 3). In general, CV-S were the dominant vessel type in all regions. The pattern of total catch by vessel type fishing in each region was also consistent across years – CPs had the highest catches in the BS and the AI, and CV-S were dominant in the GOA (Table 4).

Because the BS and AI are managed as a unit for most target species, fishing months are summarized for the BS and AI combined and for the GOA (Figure 2). In general, trawling occurred January through October across years, although fishing days varied for some target fisheries in both regions (Figure 2). Exceeding total allowable target catch or prohibited species catch limits in a given target fishery accounted for most target fishery differences in fishing months across years. More fishing days were available in the BSAI for the pollock and cod target fisheries than the GOA, whereas the GOA has more flatfish and rockfish days available. Although not obvious in Figure 2, which is generalized by month, GOA openings tended to be more intermittent than continuous.

Trawling in Alaska occurred from 148 degrees west to 165 degrees east longitude and 52 degrees to 61 degrees north latitude. The majority of warp and third-wire effort (hours) occurred between 50 and 200 meters in depth, with a heavy concentration in the southern Bering Sea (Figure 3).

Total warp effort during the tows declined slightly (5%) from 2003 to 2005 (Table 5; 378,214 hours to 359,550 hours) and was driven by variation within target fishery and vessel type. The pollock fishery accounted for the largest proportion of warp effort overall (44-50% of total hours) followed by flatfish (24-27%) and cod (20-23%). Most effort occurred in the Bering Sea in all years (78%, 83% and 81% in 2003, 2004 and 2005 respectively).

Total third-wire effort during tows was nearly one-quarter of total warp effort, and unlike warp effort, third-wire effort increased from 2003 to 2005 by 7 percent (from 90,161 to 96,579 hours; Table 6). Overall, both CV-S and CV-M third-wire effort increased (26% and 5%, respectively) and was dominant overall, while CP effort decreased (11%). The pollock fishery accounted for most third-wire effort (80-82% of total hours) followed by flatfish (11-13%) and cod (6-7%). Regionally, most third-wire effort occurred in the Bering Sea (92%, 94% and 93% in 2003, 2004 and 2005 respectively). Although the vessel-specific information received was not complete for all vessel types and fishery combinations (Table 7), we feel these results are representative, albeit an underestimate of actual third-wire effort (due to the likely omission of vessels that used third wires).

Target Fisheries: Pollock

Pollock is the largest target fishery in Alaska, involving the largest number and greatest diversity of vessels, as well as the largest catch. Each vessel class will be described separately.

Fleet Description: Pollock

Bering Sea Catcher-Processors: Twenty-three unique CPs targeted BS pollock in 2003-05; however, only 16 targeted pollock as their primary fishery (defined as >90% catch in pollock target fishery)[7]. The primary pollock CPs ranged from 201 to 376 feet long. Of these, eight vessels occasionally participated in the BS flatfish fishery, one participated in the AI Atka mackerel fishery, and two participated in the AI pollock fishery. The following summary of vessel characteristics is specific to the 16 CPs primarily targeting pollock in the BS and was generated from information provided by the Alaska trawl industry via our questionnaire.

All warp cables were made of steel, had an average diameter of 35.3 millimeters and were only spliced at the ends where the warps attached to the winches and doors. Most warp blocks were either 15-20 feet (nine vessels) or 20-25 feet (four vessels) above sea level, and all but one were positioned inboard near the vessel's stern (A in Appendix A, Diagram 2). The reported distance astern where warps entered the water varied widely (10-20 ft, one vessel; 20-30 ft, six vessels; 30-60 ft, 6 vessels; >60 ft, 3 vessels).

During the pollock fishery, CPs deployed a third wire on all tows. All third-wire cables were made of coaxial cable sheathed with steel and had an average diameter of 11.7 millimeters. Most third wire blocks were either 20-25 feet (six vessels) or 25-30 feet (eight vessels) above sea level, and all but two were centrally positioned slightly aft of the stern (F in Appendix A, Diagram 2). The reported distance astern that the third wire entered the water varied widely (25-50 ft, two vessels; 50-75 ft, three vessels; 75-100 ft, seven vessels; >100 ft, four vessels).

Vessels reported that shortwiring was common in this fishery (45% of hauls on average; range, 20-90%). Turning was also common (average 1.8 turns per haul; range: zero to three).

All 16 vessels reported the ability to process fillets and surimi, 13 produced mince, nine had fishmeal plants on board, and seven vessels made fish oil as well as meal.

Bering Sea Catcher Vessels: Ninety-five unique CVs targeted BS pollock in 2003-05; however, only 67 targeted pollock as their primary fishery (defined as >90% catch in pollock target fishery). Of these, more than half also made at least one cod landing. Seventy-seven CV-S delivered exclusively to shore-based processing facilities, seven CV-M delivered unsorted codends to motherships, and 11 vessels delivered to both motherships and to shore-based facilities. A detailed summary of vessel characteristics is not available because only one questionnaire was returned from this fleet; however, based on industry input, we assumed for the analysis estimating third-wire effort that all vessels longer than 100 feet used third wires when targeting pollock (70/95 vessels in this class; United Catcher Boats, pers. comm.).

Gulf of Alaska Catcher Vessels: Eighty-one unique CV-S landed GOA pollock in 2003-05. Vessels ranged from 58 to 124 feet long. This

[7] For more information about this fleet of vessels, see *http://www.atsea.org/index.php* (At-Sea Processors Association).

Table 3. Number of vessels that made landings for each year and target fishery by large geographic region and vessel type (CAS data). Column and row subtotals are not additive; a vessel may have participated in more than one category. CV-S=catcher vessel delivering to shore; CP=catcher processor; CV-M= CV delivering to motherships (number of M in parentheses). *Values excluded when comprised of less than three vessels to protect confidentiality.

	Bering Sea			Aleutian Islands			Gulf of Alaska		All Regions			
	CV-S	CP	CV-M	CV-S	CP	CV-M	CV-S	CP	CV-S	CP	CV-M	Total
2003												
Pollock	85	18	18 (3)	0	0	0	71	0	133	18	19 (3)	154
Cod	65	17	*	30	10	3 (1)	67	6	123	20	3 (1)	143
Flatfish	0	26	*	*	*	0	31	16	32	27	*	59
Atka	0	7	0	0	10	0	0	0	0	15	0	15
Rockfish	0	3	0	0	8	0	34	13	34	16	0	50
Other	0	7	0	0	0	0	12	3	12	10	0	22
Total	**103**	**39**	**20 (5)**	**30**	**14**	**3 (1)**	**87**	**21**	**157**	**40**	**21 (5)**	**200**
2004												
Pollock	86	18	18 (3)	0	0	0	68	0	132	18	18 (3)	153
Cod	59	20	*	18	10	3 (2)	62	6	114	20	3 (3)	134
Flatfish	*	27	*	0	0	0	29	8	30	27	*	57
Atka	0	11	0	0	10	0	0	0	0	19	0	19
Rockfish	*	3	0	0	6	0	32	13	32	15	0	47
Other	0	5	0	0	*	0	5	*	6	7	0	13
Total	**99**	**40**	**19 (5)**	**18**	**15**	**3 (2)**	**77**	**16**	**146**	**40**	**20 (6)**	**189**
2005												
Pollock	84	21	18 (3)	0	3	0	66	0	129	22	18 (3)	154
Cod	55	16	*	14	8	*	65	3	108	20	*	128
Flatfish	0	27	*	0	0	0	28	8	28	28	*	55
Atka	0	11	0	0	10	0	0	0	0	19	0	19
Rockfish	0	*	0	0	5	0	25	10	25	13	0	38
Other	0	*	0	0	0	0	*	*	*	3	0	5
Total	**98**	**39**	**19 (5)**	**14**	**15**	*****	**78**	**16**	**145**	**40**	**19 (5)**	**187**

Table 4. Landing weight (metric tons) for each year and target fishery by large geographic region and vessel type (CAS data). Column and row totals do not match actual total because a vessel may have participated in more than one category. CV-S=catcher vessel delivering to shore; CP=catcher processor; CV-M= CV delivering to motherships; dash=no fishing; nd=no data. *Values excluded when comprised of less than three vessels to protect confidentiality.

	Bering Sea			Aleutian Islands			Gulf of Alaska		All Regions			
	CV-S	CP	CV-M	CV-S	CP	CV-M	CV-S	CP	CV-S	CP	CV-M	Total
2003												
Pollock	658,593	657,449	152,682	-	-	-	50,663	-	709,257	657,449	152,682	1,519,388
Cod	31,731	25,304	*	14,705	15,197	3,256	14,600	1,475	61,036	41,976	3,327	106,339
Flatfish	-	171,428	*	*	*	-	13,006	30,745	13,006	202,173	*	215,179
Atka	-	809	-	-	61,491	-	-	-	-	62,300	-	62,300
Rockfish	-	136	-	-	15,416	-	13,524	11,968	13,524	27,520	-	41,043
Other	-	783	-	-	-	-	1,842	463	1,842	1,245	-	3,087
Total	**690,324**	**855,909**	**152,682**	**14,705**	**92,104**	**3,256**	**93,636**	**44,650**	**798,665**	**992,663**	**156,009**	**1,947,336**
2004												
Pollock	645,717	655,952	151,233	-	-	-	64,981	-	710,697	655,952	151,233	1,517,883
Cod	31,446	51,136	*	11,069	12,336	2,779	14,388	2,356	56,902	65,829	2,795	125,525
Flatfish	*	181,366	*	-	-	-	12,343	8,058	12,425	189,424	*	201,902
Atka	-	2,211	-	-	63,032	-	-	-	-	65,242	-	65,243
Rockfish	*	73	-	-	11,897	-	12,478	13,640	12,620	25,609	-	38,229
Other	-	278	-	-	*	-	399	*	400	494	-	893
Total	**677,385**	**891,026**	**151,303**	**11,069**	**87,287**	**2,779**	**104,590**	**24,248**	**793,044**	**1,002,561**	**154,082**	**1,949,686**
2005												
Pollock	656,712	657,570	148,067	-	402	-	83,914	-	740,626	657,972	148,067	1,546,665
Cod	28,026	32,605	*	7,406	11,357	*	11,737	578	47,169	44,540	*	91,709
Flatfish	-	192,185	*	-	-	-	15,718	13,952	15,718	206,136	*	221,854
Atka	-	2,342	-	-	67,331	-	-	-	-	69,673	-	69,673
Rockfish	-	*	-	-	9,542	-	10,012	13,033	10,012	22,606	-	32,618
Other	-	*	-	-	-	-	*	*	*	83	-	83
Total	**684,738**	**884,780**	**149,209**	**7,406**	**88,632**	*****	**121,381**	**27,600**	**813,525**	**1,001,012**	**150,276**	**1,964,812**

Table 5. Estimated warp effort (hours) during tow period for each year and target fishery by large geographic region and vessel type (NPGOP data). CV-S=catcher vessel delivering to shore; CP=catcher processor. CV-M= CV delivering to motherships; dash=no fishing; nd=no data; *Values excluded when comprised of less than three vessels to protect confidentiality.

	Bering Sea			Aleutian Islands			Gulf of Alaska		All Regions			
	CV-S	CP	CV-M	CV-S	CP	CV-M	CV-S	CP	CV-S	CP	CV-M	Total
2003												
Pollock	78,526	49,224	21,711	-	-	-	15,237	-	93,763	49,224	21,711	164,697
Cod	51,458	19,607	*	3,827	5,554	1,699	6,335	294	61,620	25,455	1,699	88,774
Flatfish	-	71,606	*	nd	*	-	11,273	20,280	11,273	91,909	*	103,228
Atka	-	474	-	-	6,642	-	-	-	-	7,116	-	7,116
Rockfish	-	79	-	-	1,700	-	6,278	3,407	6,278	5,186	-	11,463
Other	-	638	-	-	-	-	2,297	*	2,297	638	-	2,935
Total	**129,984**	**141,627**	**21,837**	**3,827**	**13,896**	**1,699**	**41,420**	**23,981**	**175,230**	**179,527**	**23,410**	**378,214**
2004												
Pollock	91,049	47,131	20,607	-	-	-	16,921	-	107,970	47,131	20,607	175,707
Cod	36,314	30,950	nd	2,997	4,583	1,207	6,992	1,217	46,302	36,750	1,207	84,259
Flatfish	*	74,038	*	-	-	-	9,176	3,620	9,176	77,658	*	86,834
Atka	-	964	-	-	7,557	-	-	-	-	8,521	-	8,521
Rockfish	nd	52	-	-	1,158	-	5,051	2,679	5,051	3,889	-	8,940
Other	-	600	-	-	*	-	722	*	722	609	-	1,331
Total	**127,469**	**153,735**	**20,607**	**2,997**	**13,298**	**1,207**	**38,862**	**7,516**	**169,222**	**174,558**	**21,813**	**365,593**
2005												
Pollock	98,567	40,026	19,384	-	57	-	22,659	-	121,227	40,083	19,384	180,694
Cod	32,262	27,638	*	2,096	4,038	*	4,117	*	38,475	31,676	898	71,049
Flatfish	-	71,585	*	-	-	-	7,988	10,126	7,988	81,711	*	89,699
Atka	-	1,313	-	-	8,357	-	-	-	-	9,670	-	9,670
Rockfish	-	*	-	-	1,008	-	5,037	2,233	5,037	3,242	-	8,279
Other	-	*	-	-	-	-	*	*	*	158	-	158
Total	**130,829**	**140,614**	**20,143**	**2,096**	**13,460**	*****	**39,802**	**12,789**	**172,727**	**166,540**	**20,283**	**359,550**

Table 6. Estimated third-wire effort (hours) during tow period for each year and target fishery by large geographic region and vessel type (NPGOP data). CV-S=catcher vessel delivering to shore; CP=catcher processor; CV-M= CV delivering to motherships; dash=no fishing; nd=no data. *Values excluded when comprised of less than three vessels to protect confidentiality.

	Bering Sea			Aleutian Islands			Gulf of Alaska		All Regions			
	CV-S	CP	CV-M	CV-S	CP	CV-M	CV-S	CP	CV-S	CP	CV-M	Total
2003												
Pollock	36,148	24,612	7,349	-	-	-	4,009	-	40,157	24,612	7,349	72,118
Cod	*	4,138	*	*	1,065	*	13	41	310	5,245	*	5,554
Flatfish	-	10,267	nd	nd	nd	-	0	1,410	nd	11,677	nd	11,677
Atka	-	32	-	-	186	-	-	-	-	218	-	218
Rockfish	-	0	-	-	0	-	53	529	53	529	-	582
Other	-	12	-	-	-	-	0	*	*	12	-	12
Total	**36,148**	**39,061**	**7,349**	*****	**1,251**	*****	**4,075**	**1,980**	**40,520**	**42,292**	**7,349**	**90,161**
2004												
Pollock	42,496	23,565	7,228	-	-	-	3,659	-	46,155	23,565	7,228	76,948
Cod	nd	4,910	nd	*	938	nd	*	88	309	5,936	nd	6,245
Flatfish	*	9,787	*	-	-	-	0	113	0	9,900	*	9,900
Atka	-	9	-	-	199	-	-	-	-	209	-	209
Rockfish	nd	0	-	-	0	-	27	313	27	313	-	340
Other	-	0	-	-	nd	-	0	nd	0	0	-	0
Total	**42,496**	**38,272**	**7,228**	*****	**1,137**	**nd**	**3,686**	**514**	**46,491**	**39,923**	**7,228**	**93,641**
2005												
Pollock	46,157	20,013	7,709	-	29	-	4,642	-	50,799	20,042	7,709	78,549
Cod	*	5,299	*	*	957	*	90	nd	255	6,256	*	6,511
Flatfish	-	10,578	nd	-	-	-	0	2	0	10,581	nd	10,581
Atka	-	28	-	-	578	-	-	-	-	606	-	606
Rockfish	-	nd	-	-	0	-	54	278	54	278	-	332
Other	-	*	-	-	-	-	nd	*	*	*	-	0
Total	**46,157**	**35,918**	**7,709**	*****	**1,564**	*****	**4,786**	**280**	**51,108**	**37,762**	**7,709**	**96,579**

Table 7. Number of vessels using a third wire for at least some portion of their fishing time by target fishery, region and vessel type based on industry questionnaire. Second numbers (after slash) are total number of industry questionnaire responses per category; note these do not match totals in Table 3. CV-S=catcher vessel delivering to shore; CP=catcher processor; CV-M= CV delivering to motherships; dash=no fishing; nd=no data. †Pollock vessels >100 ft assumed to use third wire 100% of time (70/95 vessels).

	Bering Sea			Aleutian Islands			Gulf of Alaska	
	CV-S	CP	CV-M	CV-S	CP	CV-M	CV-S	CP
Pollock	nd†	16 / 19	nd†	-	2 / 3	-	24 / 51	-
Cod	1 / 10	7 / 14	nd	2 / 12	3 / 4	nd	2 / 35	2 / 4
Flatfish	nd	12 / 23	nd	nd	nd	-	0 / 16	4 / 10
Atka	-	4 / 10	-	-	2 / 9	-	-	-
Rockfish	nd	0 / 4	-	-	0 / 7	-	1 / 12	2 / 12

fleet was much more diverse (in terms of target species) than the BS pollock CV-S, and vessels were generally smaller; therefore, vessels less than 60 feet and longer than 60 feet are described separately. In general, GOA CV-S do not shortwire, and fish discards, when they occur, are whole fish.

Gulf of Alaska Catcher Vessels less than 60 feet (pollock and cod targets): Thirty-two vessels less than 60 feet landed groundfish, although pollock (two vessels), cod (nine vessels) or the combination of pollock and cod (21 vessels) made up more than 90 percent of landing weight. Responses to the industry questionnaire were obtained for 23 vessels in this class. Warp cables averaged 15.9 millimeters (5/8") and were made of steel. Splices only occurred if a warp cable broke; however, respondents said these were generally replaced within the fishing year. Warp cables entered water close to the stern (within 10 ft). None employed a third wire.

Gulf of Alaska Catcher Vessels longer than 60 feet (pollock, cod, flatfish and rockfish targets): Fifty-eight CV-S longer than 60 feet landed pollock in 2003-05, although only 35 had pollock consisting of more than 50 percent of the catch. All CV-S longer than 60 feet also participated in at least one other groundfish target fishery (cod, flatfish, rockfish or other) in the GOA.

Twenty-five CV-S in this class reported that warps were made of steel, had an average warp diameter of 19.3 millimeters, and splices were not present except on the end where warp cables attached to winches. Most warp blocks were 10-15 feet (21 vessels) or 15-20 feet (3 vessels) above sea level, and 21 were positioned slightly outboard and forward of the stern (D in Appendix A, Diagram 2). Nearly half (n=11) of the vessels estimated the distance astern that warps entered the water at 20-30 feet, whereas the other half (12 vessels) estimated 30-60 feet.

During the pollock fishery, 12 vessels deployed a third wire on the majority of trawls. Vessels reported that all third-wire cables were made of coated plastic and had an average diameter of 12 millimeters. Not enough information was provided to generalize for third-wire block height or position. The distance astern that the third wire entered the water was estimated at 75-100 feet (seven vessels) and more than 100 feet (one vessel). Shortwiring was rare for CV-S vessels.

Warp and Third-Wire Effort: Pollock

Bering Sea: Although pollock catch for each vessel type remained fairly constant during the 2003-2005 time period (Table 4), annual CV-S warp effort increased by 26 percent (20,000 hours), while CP warp effort decreased by 19 percent (> 9,000 hours), and CV-M warp effort decreased by 11 percent (Table 5). Consequently, overall CP warp effort was less than a third the total for BS pollock (33% in 2003, 30% in 2004, 25% in 2005). The change in CV-S catch efficiency (mt of catch/hour fished) was due to salmon bycatch area closures during this time period, which forced the CV-S fleet to fish in areas with lower pollock catch rates (J. Gruver, pers.com., August 3, 2007). A similar increase (28%) was observed for CV-S third-wire effort (Table 6).

The BS pollock fishery is open from January 20 to October 31 each year but is managed using cooperative (contractual) agreements among fleet sectors, which allows for flexible fishing seasons and eliminates the race for fish. Fishing occurred in two seasons (A-season: January through March and B-season: mid-June through September). Peak effort occurred in February for the A-season (Figure 4) because, unlike January and March, February constituted a full fishing month. The B-season effort peak also tended to be higher and more sustained over July to September (Figure 4).

The BS pollock fishery occurs primarily on the continental shelf between the 50-meter and 200-meter depth. Both warp and third-wire effort were most concentrated along the 100-meter isobath and in the southern BS (Figure 5). Considering the temporal component of this spatial description, the fishery began in the southern BS (below 56ºN) at the start of A-season and slowly progressed north to higher latitudes in the spring and summer, depending on catch conditions and sea ice extent (Figure 6).

In the BS, 100 percent coverage vessels accounted for the majority of effort (>60%), whereas in the GOA, 30 percent coverage vessels accounted for all effort. We were unable to gather detailed information on cable distances astern for CV-S and CV-M vessels; however, all primary CPs provided information via the industry questionnaire. More than half of warp effort occurred at warp distances astern between 20 and 60 feet, with a near equal split among the 20-30 foot and 30-60 foot categories (Table 8). Over half of the CP third-wire effort was by cables extending beyond 75 feet astern.

Table 8. Pollock warp (A) and third-wire (B) effort (hours) during the tows by cable distance astern, region and processor type (NPGOP data and industry questionnaire). Aleutian Islands excluded due to no fishing in 2003-2004 and too few vessels in 2005. BS=Bering Sea; GOA=Gulf of Alaska; CV-S=catcher vessel delivering to shore; CP=catcher processor; CV-M= CV delivering to motherships; nd=no data. *Values excluded when comprised of less than three vessels to protect confidentiality.

A

Year	Distance astern	BS			GOA
		CV-S	CP	CV-M	CV-S
2003	Unknown	78,526	*	21,711	7,019
	10-20 ft	nd	4,144	nd	nd
	20-30 ft	nd	17,496	nd	3,246
	30-60 ft	nd	17,647	nd	4,972
	>60 ft	nd	9,615	nd	nd
2004	Unknown	91,049	*	20,607	7,988
	10-20 ft	nd	3,384	nd	292
	20-30 ft	nd	15,933	nd	2,868
	30-60 ft	nd	17,698	nd	5,774
	>60 ft	nd	10,115	nd	nd
2005	Unknown	98,567	*	19,384	10,041
	10-20 ft	nd	3,078	nd	295
	20-30 ft	nd	13,074	nd	5,103
	30-60 ft	nd	14,297	nd	7,221
	>60 ft	nd	9,577	nd	nd

B

Year	Distance astern	BS			GOA
		CV-S	CP	CV-M	CV-S
2003	Unknown	36,148	*	7,349	2,048
	25-50 ft	nd	3,884	nd	nd
	50-75 ft	nd	4,723	nd	nd
	75-100 ft	nd	9,388	nd	27
	>100 ft	nd	6,407	nd	5
2004	Unknown	42,496	*	7,228	1,902
	25-50 ft	nd	3,670	nd	146
	50-75 ft	nd	4,151	nd	nd
	75-100 ft	nd	9,136	nd	1,512
	>100 ft	nd	6,544	nd	99
2005	Unknown	46,157	*	7,709	2,297
	25-50 ft	nd	2,908	nd	148
	50-75 ft	nd	3,449	nd	nd
	75-100 ft	nd	7,514	nd	1,943
	>100 ft	nd	5,859	nd	254

Aleutian Islands: The AI were closed to directed pollock trawling from 1999 through 2004 due to Steller sea lion conservation measures. Responding to a small quota (2,600 mt)[8] allocated in 2005, three CPs participated in the AI fishery, although we excluded warp and third-wire distance astern details from Table 8 to protect vessel confidentiality.

Gulf of Alaska: The GOA pollock season was shorter than the BS season (Figure 2) and had many brief openings (one to five days) throughout the year, primarily January-March and August-October. Consequently, both warp and third-wire effort in the GOA are nearly one-fifth of BS effort (Tables 5-6; Figure 7). In the GOA, pollock effort was concentrated around Kodiak Island (Figure 5).

Target Fisheries: Pacific Cod

Cod is the second-largest target fishery in Alaska in terms of number of vessels and had the third-largest catch.

Fleet Description: Pacific Cod

Catcher processors: Twenty-one unique CPs participated in the cod fishery during 2003-2005 – seven in one region, 11 in two regions and three in all three regions. Three vessels acted as both CPs and motherships, although the mothership component of cod catch was sizeable for only one vessel. All CPs that substantially participated in the cod fishery (16 vessels; 30% of individual vessel catch on average) also participated in the flatfish fishery. Therefore, most cod CP vessel characteristics are summarized in the flatfish section. CPs rarely shortwire (6% on average estimated by nine respondents), and responses regarding turns ranged from never to four (17 responses).

Catcher Vessels: One hundred thirty-nine unique CVs participated in the cod fishery during 2003-2005, although cod constituted more than 10 percent of catch weight for only 85. GOA CV-S that participated in the cod fishery are described more fully in the pollock section. Information was insufficient to determine characteristics of the 85 vessels in the BS and the 21 vessels longer than 60 feet that landed cod from the AI. Vessel characteristics for the 12 CV-S less than 60 feet are as described for the GOA pollock vessels of less than 60 feet.

Warp and Third-Wire Effort: Pacific Cod

Although the total number of CPs was static from 2003-2005, the number of CPs varied by region (Table 3). Total CV-M was also somewhat stable, whereas CV-S decreased by 12 percent (Table 3). Catch (Table 4) and warp effort during the tow (Table 5) were highly variable. Cod vessels accounted for 20-23 percent of the total fleet warp effort and 6-7 percent of fleet third-wire effort. Cod warp effort decreased by more than 17,000 hours from 2003 to 2005, while cod third-wire effort increased slightly by nearly 1,000 hours (Table 6). The increase in third-wire effort was driven by CPs; CV-S and CV-M contributed a very minor component of cod third-wire effort (Table 6).

The cod fishery is open to fishing in at least one region from January through October (Figure 2). Warp and third-wire effort peaked each year in the months of February, March and April, and varied considerably month to month across years (Figure 8).

The cod fishery occurred in all three regions, with the largest catch and effort occurring in the BS (Tables 4-6; Figure 8). Cod warp effort was concentrated in the southeastern BS, and to a lesser degree, around the Pribilof Islands (central BS) and Zhemchug Canyon (northwest BS; Figure 9A). Third-wire effort followed a similar pattern, although it was considerably less intensive (Figure 9B). Warp effort in the GOA and AI was nearly an order of magnitude less than in the BS, whereas third-wire effort in the GOA and AI was nearly one-fifth that in the BS. GOA cod warp effort was focused around Kodiak Island and was fairly broadly distributed across the AI (Figure 9).

More than half of the warp effort was at a cable extent less than 30 feet. A summary table for cod warp effort by cable distance is not shown due to the number of cells that would have been left blank to protect confidentiality.

Target Fisheries: Flatfish

Flatfish is the third-largest target fishery in Alaska in terms of number of vessels and had the second-largest catch.

Fleet Description: Flatfish

Catcher Processors: Thirty unique CP vessels ranging in size from 104 to 296 feet targeted flatfish during 2003 through 2005. BS CPs had the highest flatfish catch (Table 4), although the flatfish CPs operated in all three regions – 14 in the BS, 15 in the BS and GOA, and one in all three regions. This fleet targeted a variety of species in addition to flatfish, including cod (18 vessels), rockfish (12 vessels) and Atka mackerel (12 vessels). The following summary of warp and third-wire characteristics is specific to these CPs (n=12) while targeting flatfish, although, in general, their characteristics did not change while participating in other fisheries.

All warps used by flatfish CPs were made of steel, had an average diameter of 27.1 millimeters and were not spliced, except on the ends where warps attached to winches or doors. Half of the vessels reported a warp block height of 10-15 feet or 15-20 feet above sea level, and all but two were positioned inboard near the vessel's stern (A in Appendix A, Diagram #1). The distance astern that warps entered the water varied widely (10-20 feet, two vessels; 20-30 feet, eight vessels; 30-60 feet, one vessel).

Six CPs routinely deploy a third wire while fishing flatfish on approximately 78 percent of their hauls. Two of these vessels used hull-mounted systems as well as third wires. Third-wire cables were made of plastic coated cables (four vessels) or steel (one vessel) and had an average diameter of 11.5 millimeters. Most third-wire blocks were either 15-20 feet (two vessels) or 20-25 feet (four vessels) above sea level, and five were centrally positioned slightly aft of the stern (F in Appendix A, Diagram #2). The aerial extent of third wires varied widely (<25 ft to >100 ft). Shortwiring was rare in this fishery (<2% of hauls on average for primary fleet). Turning was variable; two vessels note they never turned, three responded they turn once on average per haul, and one vessel said three turns per haul was typical.

Five CPs used a hull-mounted net monitoring system exclusively, while another seven used a hull-mounted system plus a towed system (paravane) as a backup.

Headed and gutted fish were the primary product for all but one CP, which also produced fillets and mince.

Catcher Vesssels: Forty-one CVs targeted flatfish during 2003-2005; only two operated outside the GOA. GOA CV-S that participated in the flatfish fishery are described more fully in the pollock section (vessels >60 ft).

[8] For more information on quota allocations, see *http://www.fakr.noaa.gov/sustainablefisheries/specs05_06/BSAItable3.pdf*

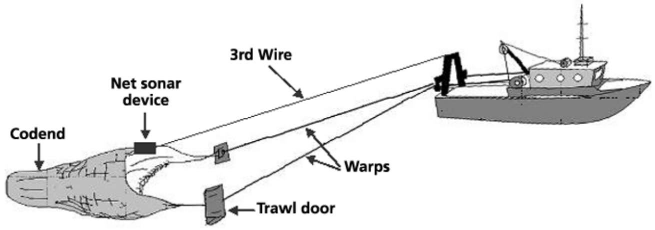


Figure 1. *Diagram of generic trawl net (courtesy of K. Williams).*

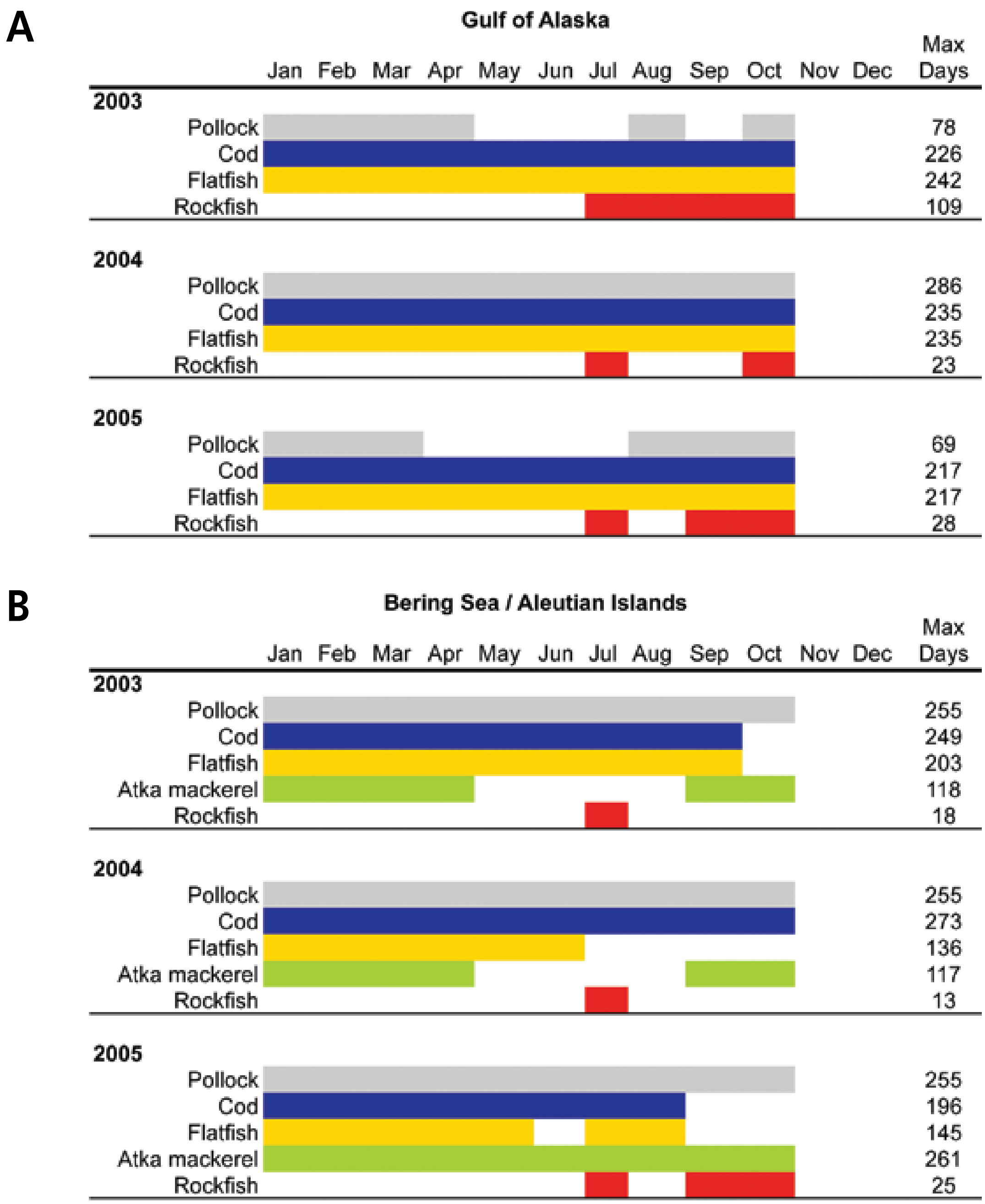


Figure 2. *Generalized fishing times by target and year in the Gulf of Alaska (A) and Bering Sea / Aleutian Islands (B). Any month with a fishing day in a given target or region is highlighted. Although some fisheries appear continuous, many (especially in the GOA) are intermittent within a month. The maximum number of days a fishery was open each year is indicated in the last column and includes all regulatory closures based on annual opening/closure tables available from NMFS Alaska Region http://www.fakr.noaa.gov.*

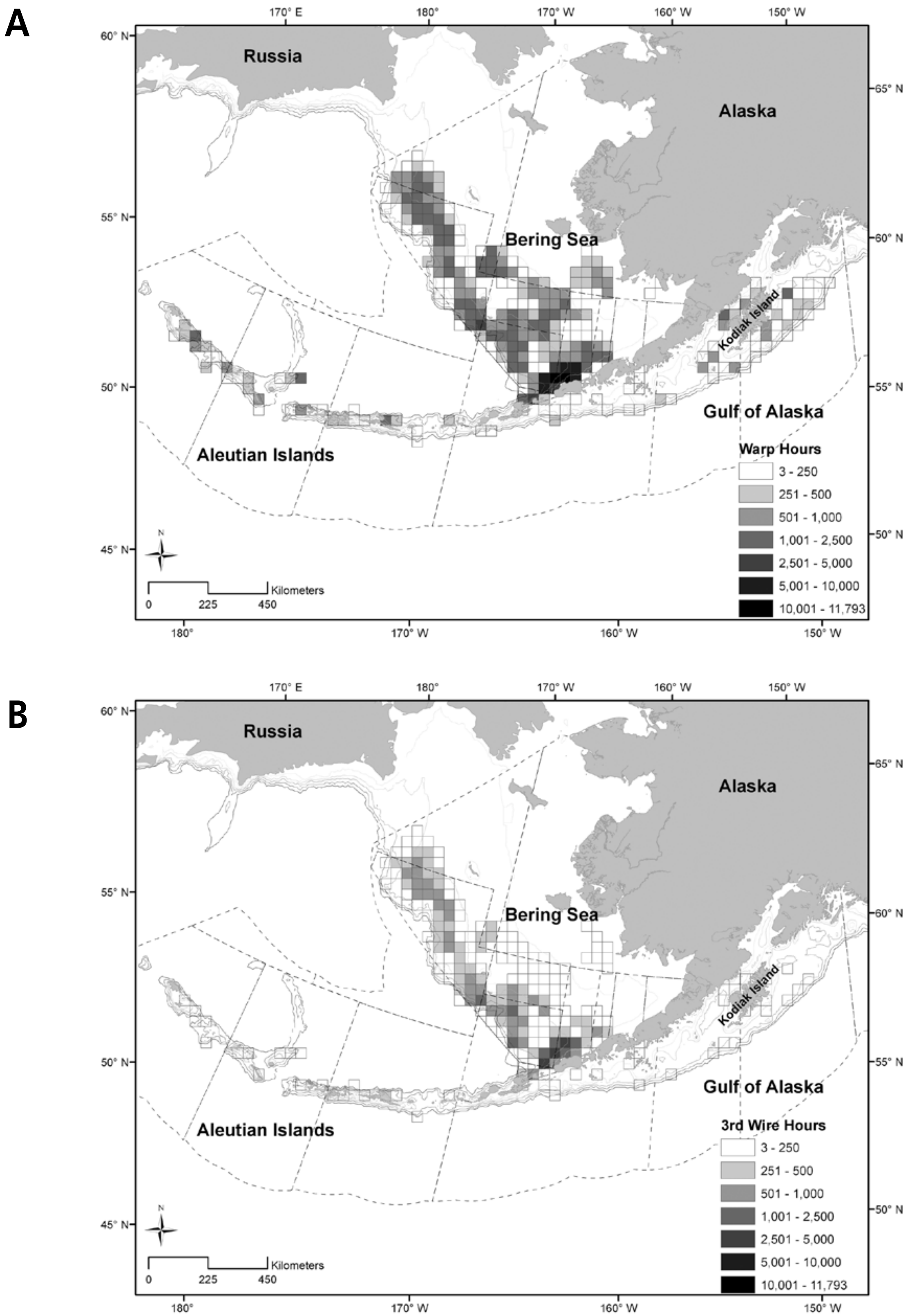


Figure 3. *Spatial distribution of 2005 warp (A) and third-wire (B) effort (hours) during tows for all target fisheries in Alaska. Dashed lines indicate U.S. exclusive economic zone and NMFS fisheries management areas. Effort is summarized within 40 km by 40 km grid cells and conforms to confidentiality requirements for presenting fishery observer data (three or more vessels fished within each cell displayed). Most cells (69%) are displayed (98% of total observed warp effort). Unobserved effort not extrapolated at the smaller spatial scale of maps.*

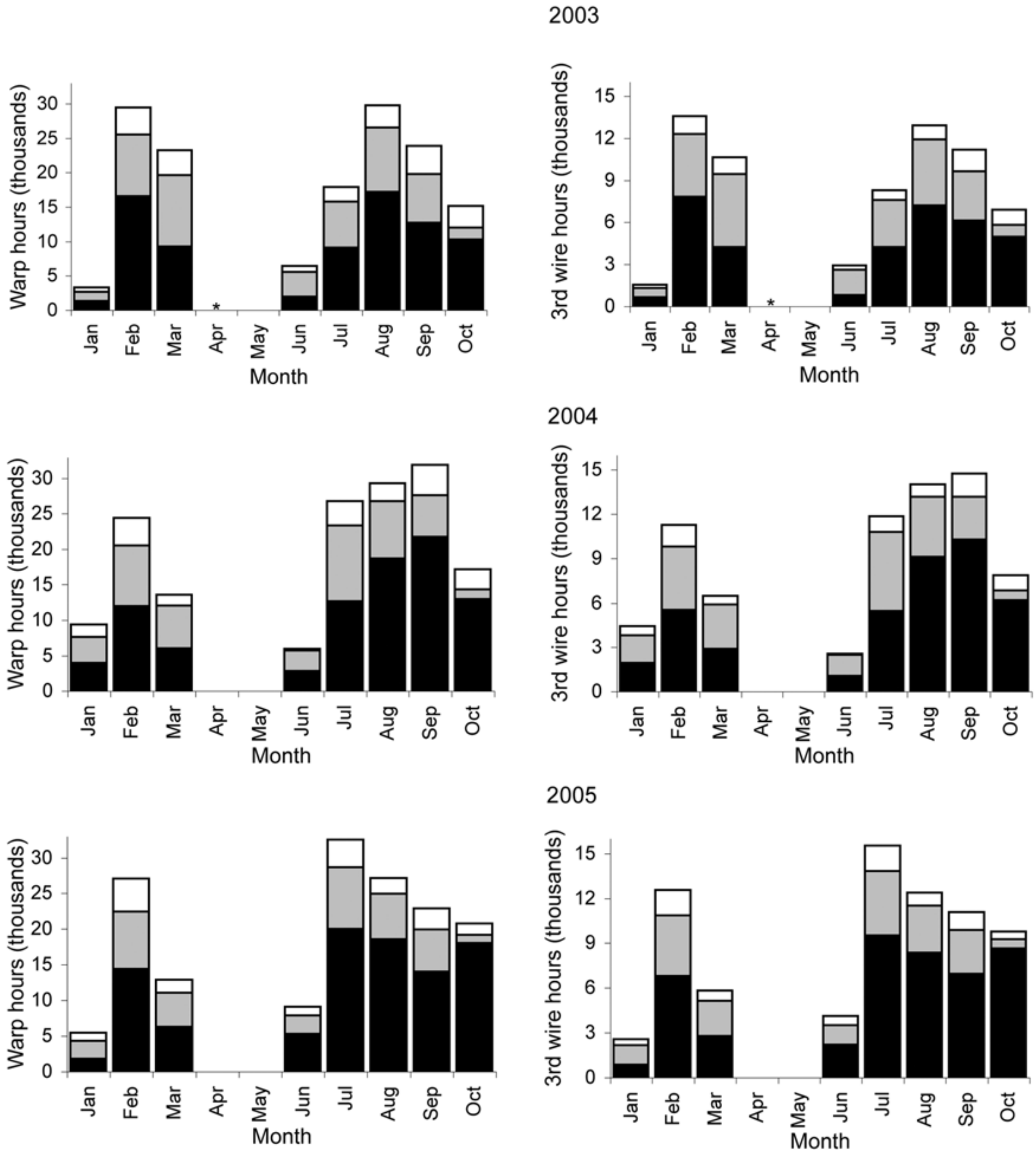


Figure 4. *Monthly warp (left panels) and third-wire (right panels) effort (hours) during tow period in 2003-2005 Bering Sea pollock fishery by vessel type. CV-M= CV delivering to motherships (white); CP: catcher processor (grey); CV-S: catcher vessel delivering to shore (solid black). *Indicates effort from at least one region excluded when comprised of less than three vessels to protect confidentiality. Note scale difference between warp and third-wire axes.*

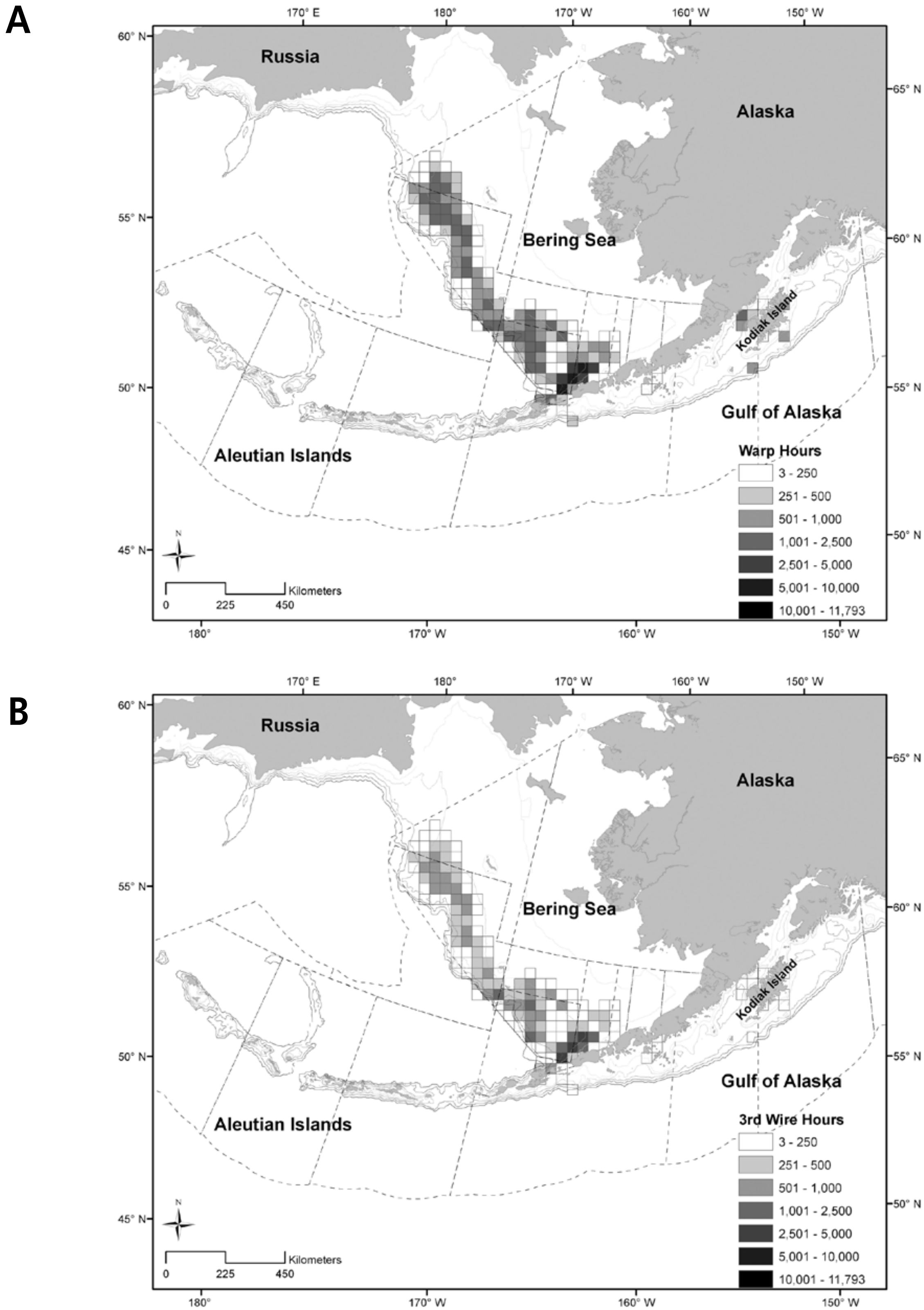


Figure 5. *Spatial distribution of 2005 pollock warp (A) and third-wire (B) effort (hours) during the tow period in Alaska. Dashed lines indicate U.S. exclusive economic zone and NMFS fisheries management areas. Effort is summarized within 40 km by 40 km grid cells and conforms to confidentiality requirements for presenting fishery observer data (three or more vessels fished within each cell displayed). Most cells (80%) are displayed (99% of total observed pollock warp effort). Unobserved effort not extrapolated at the smaller spatial scale of maps.*

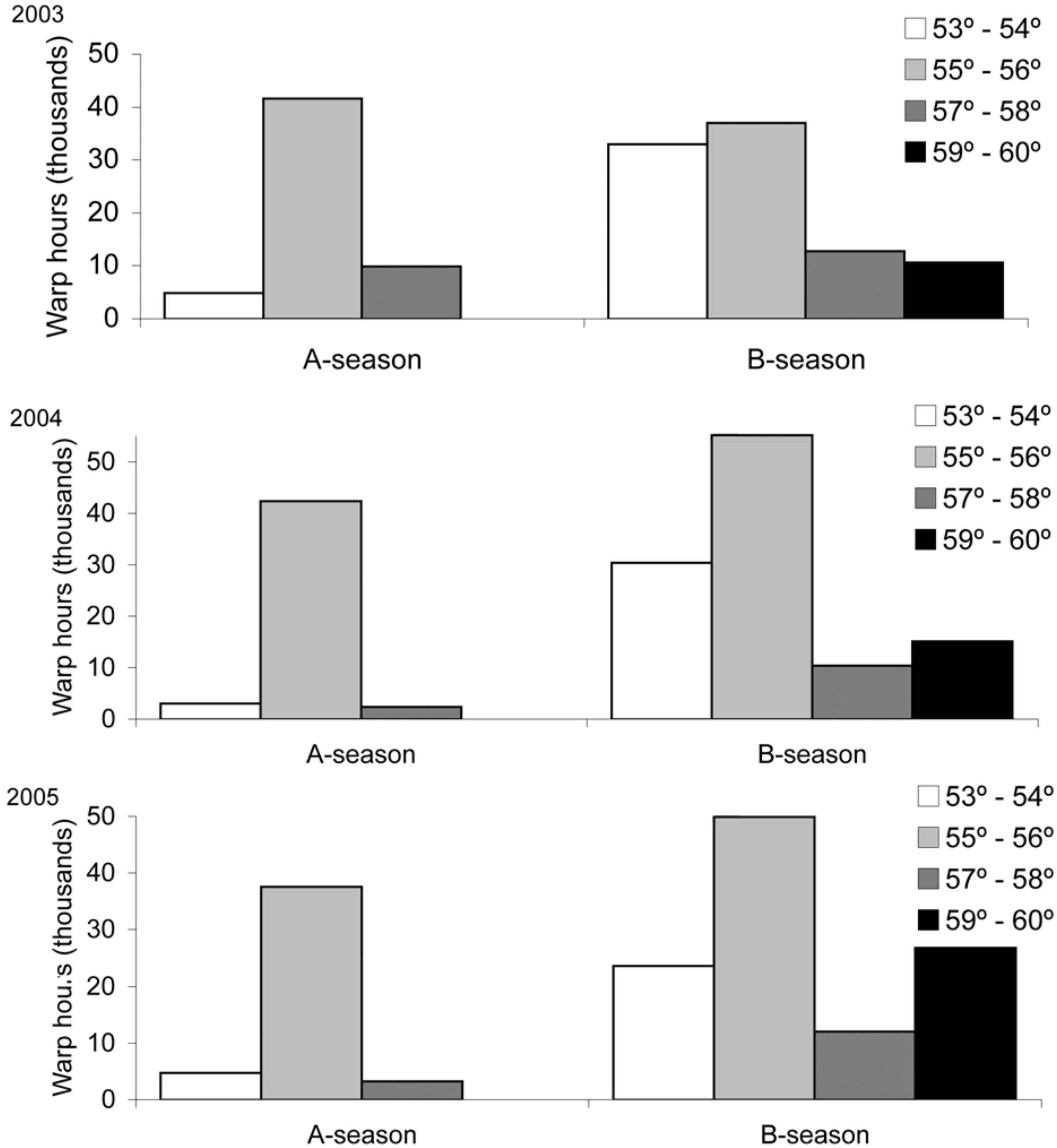


Figure 6. *Pollock warp effort during tows by season and latitude (2-degree bins) in 2003-2005.*

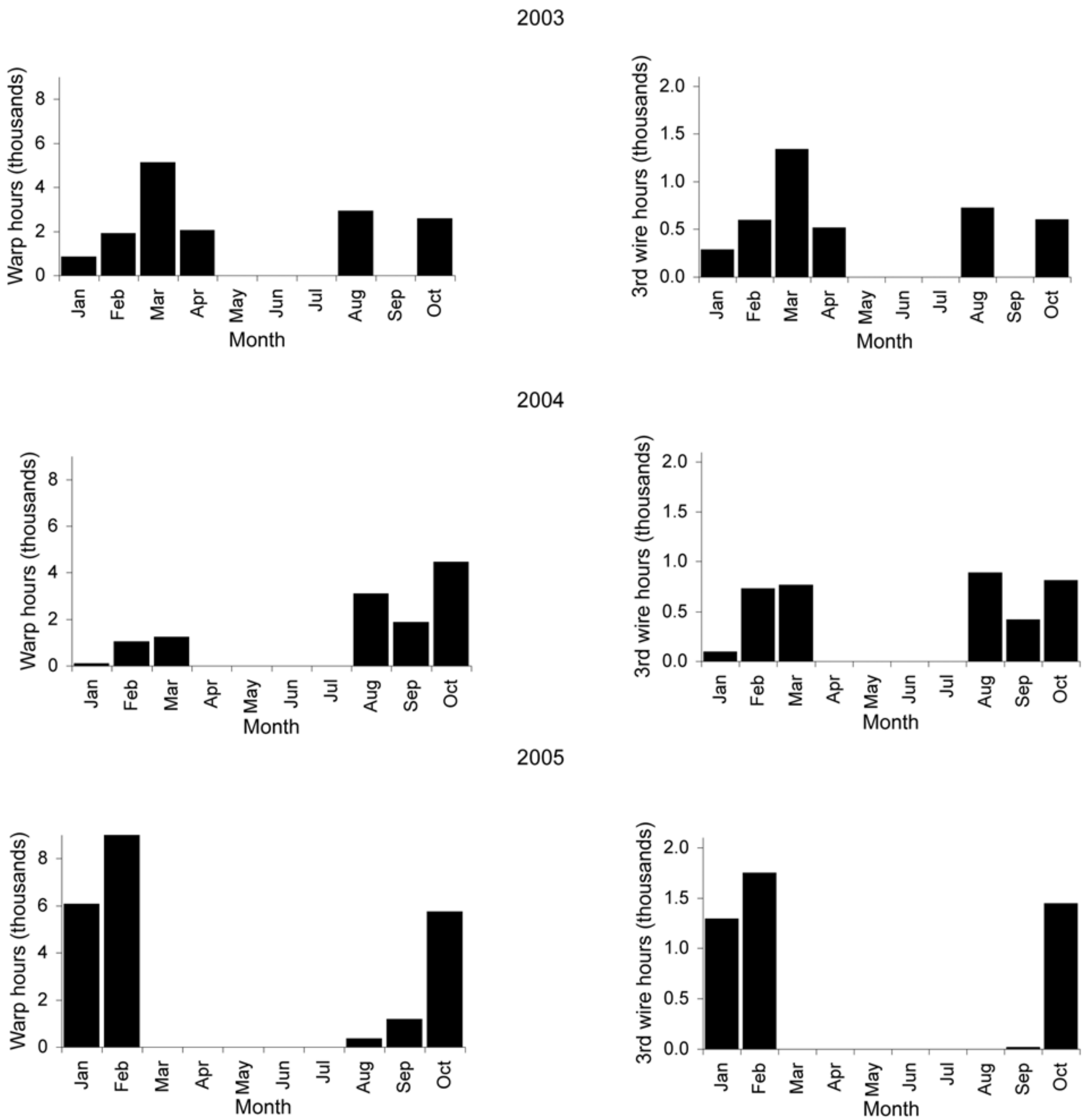


Figure 7. *Monthly warp (left panels) and third-wire (right panels) effort during tows in 2003-2005 Gulf of Alaska pollock fishery. All GOA effort by CV-S (CV delivery to shore). Note scale difference between warp and third-wire axes.*

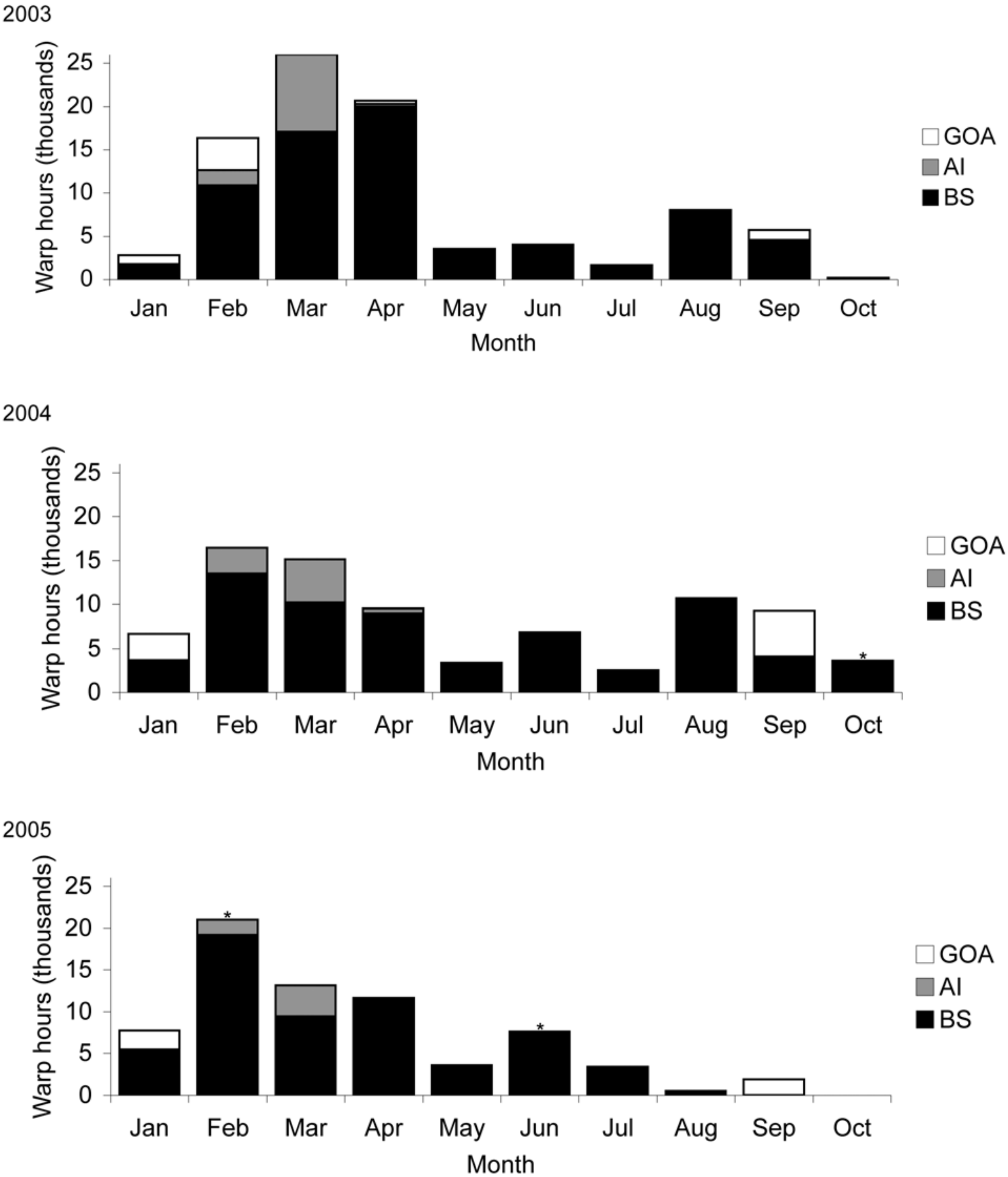


Figure 8. *Monthly warp effort during tows in the cod fishery by region and year. AI=Aleutian Islands, BS=Bering Sea; GOA=Gulf of Alaska. *Indicates effort from at least one region excluded when comprised of less than three vessels to protect confidentiality.*

A

B

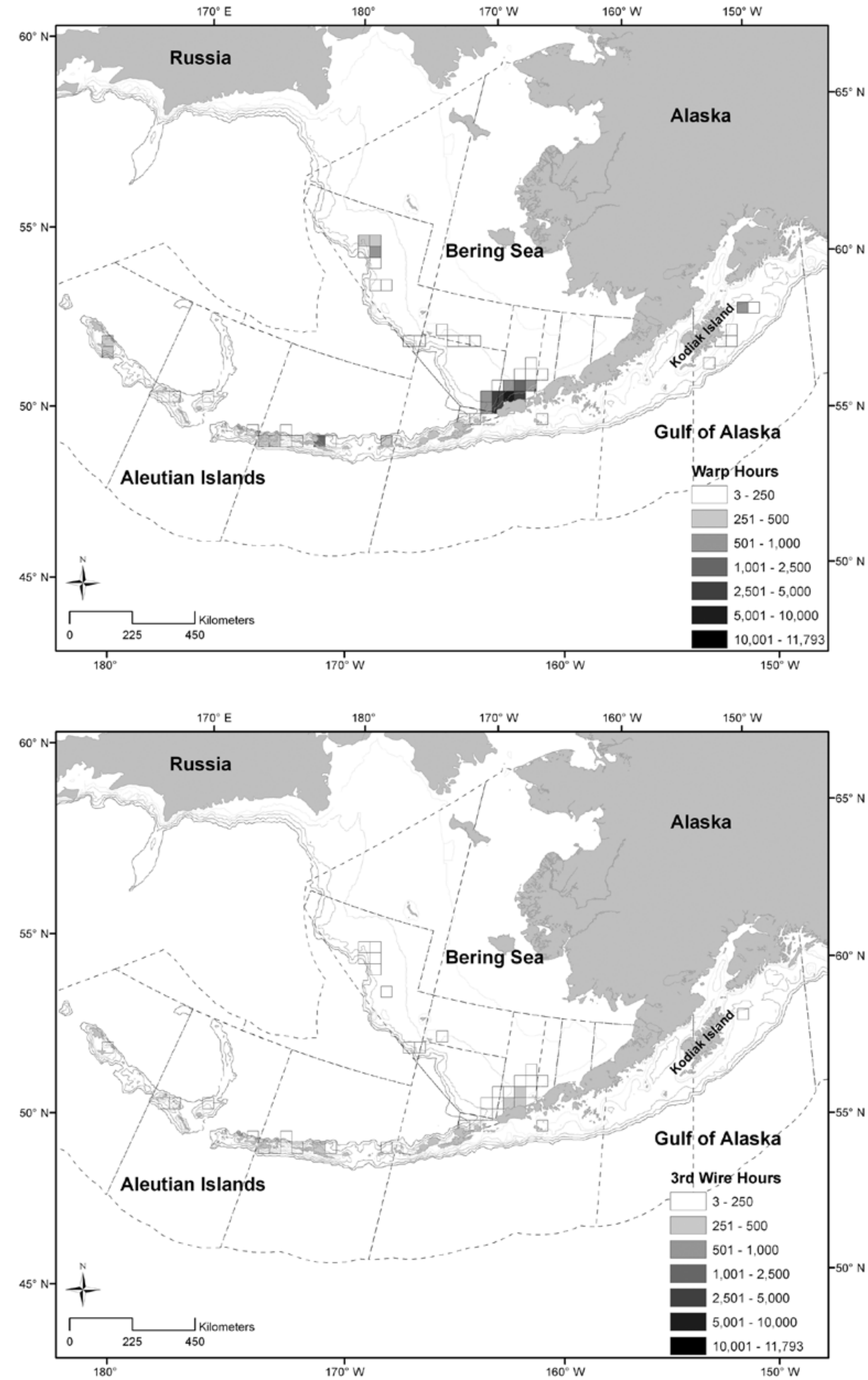


Figure 9. *Spatial distribution of 2005 cod warp (A) and third-wire (B) effort (hours) during the tow period in Alaska. Dashed lines indicate U.S. exclusive economic zone and NMFS fisheries management areas. Effort is summarized within 40 km by 40 km grid cells and conforms to confidentiality requirements for presenting fishery observer data (three or more vessels fished within each cell displayed). Only 33% of cells are displayed (94% of total observed warp effort). Unobserved effort not extrapolated at the smaller spatial scale of maps.*

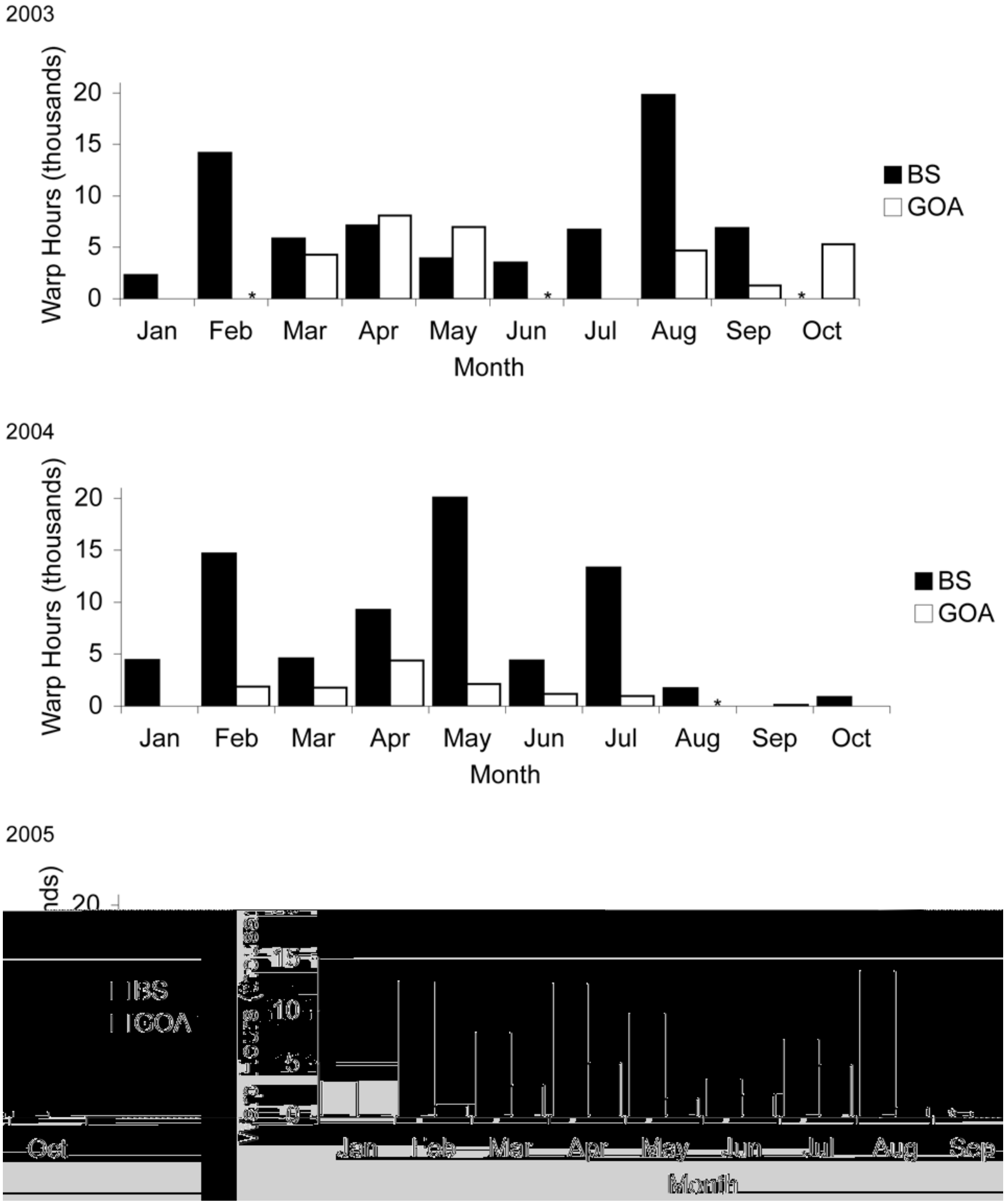
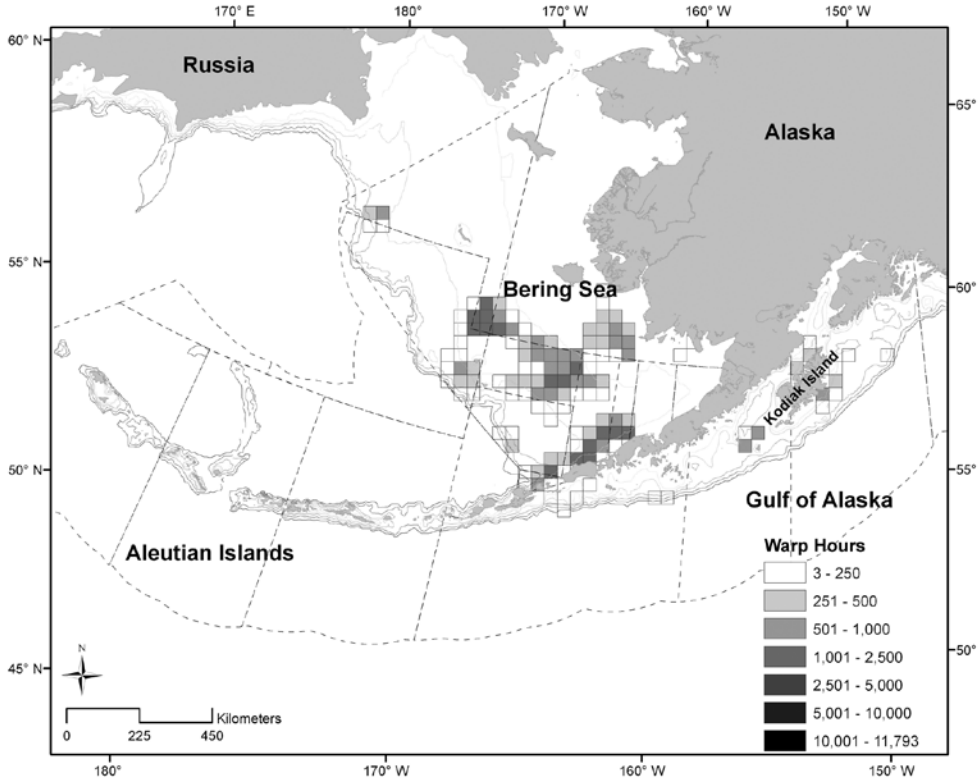


Figure 10. *Monthly warp effort during tow period in the flatfish fishery by region and year. BS=Bering Sea; GOA=Gulf of Alaska. *Indicates effort excluded when comprised of less than three vessels to protect confidentiality.*

A



B

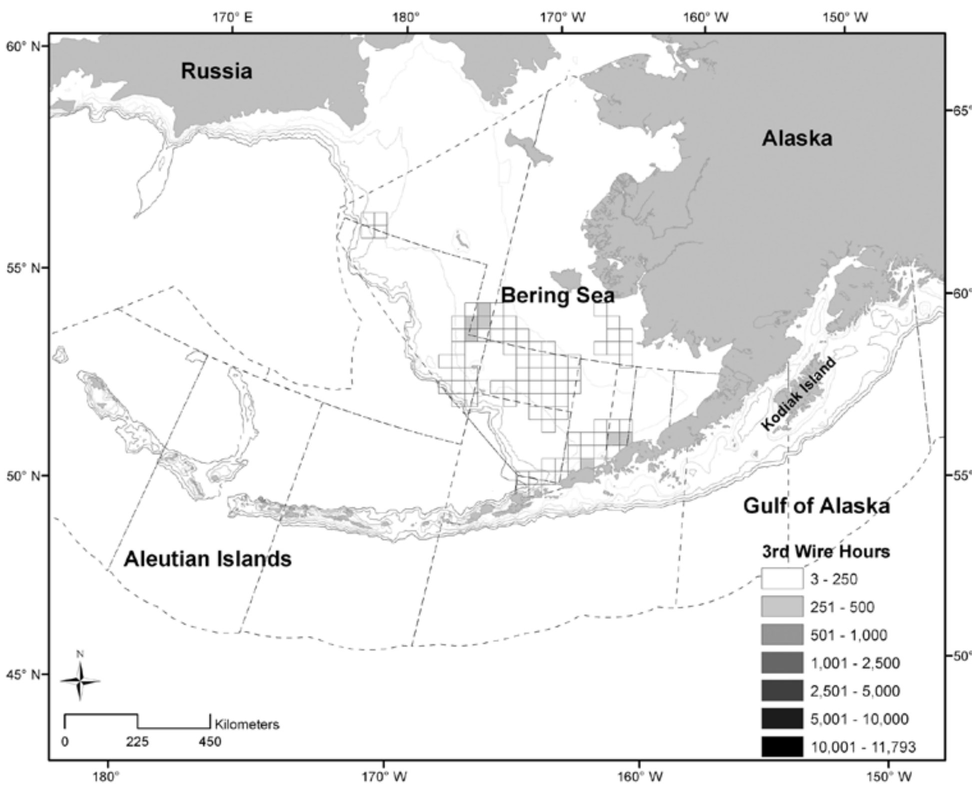


Figure 11. *Spatial distribution of 2005 flatfish warp (A) and third wire (B) effort (hours) in Alaska. Dashed lines indicate U.S. exclusive economic zone and NMFS fisheries management areas. Effort is summarized within 40 km by 40 km grid cells and conforms to confidentiality requirements for presenting fishery observer data (three or more vessels fished within each cell displayed). More than half of the cells (56%) are displayed (95% of total observed warp effort). Unobserved effort not extrapolated at the smaller spatial scale of maps.*

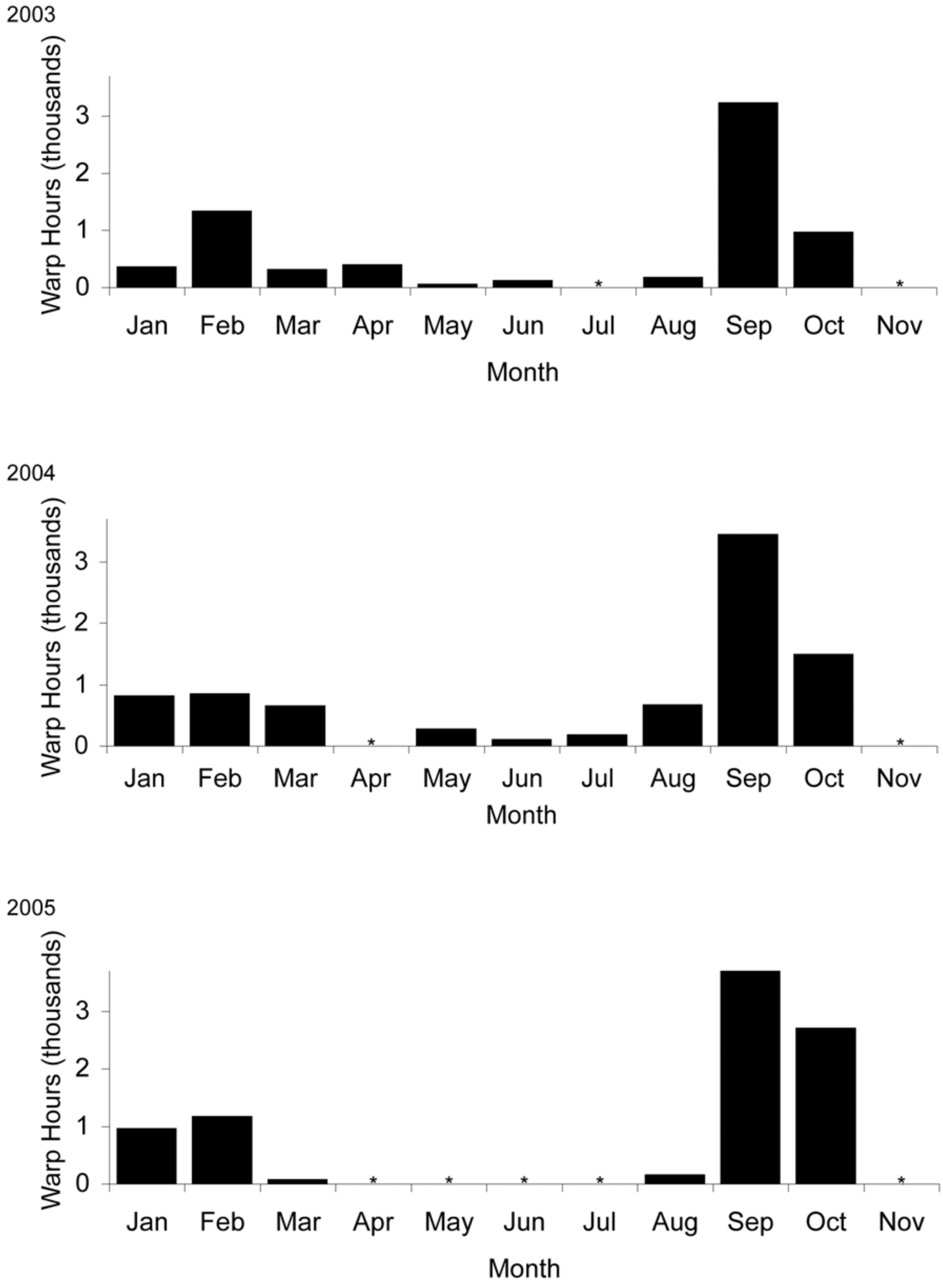
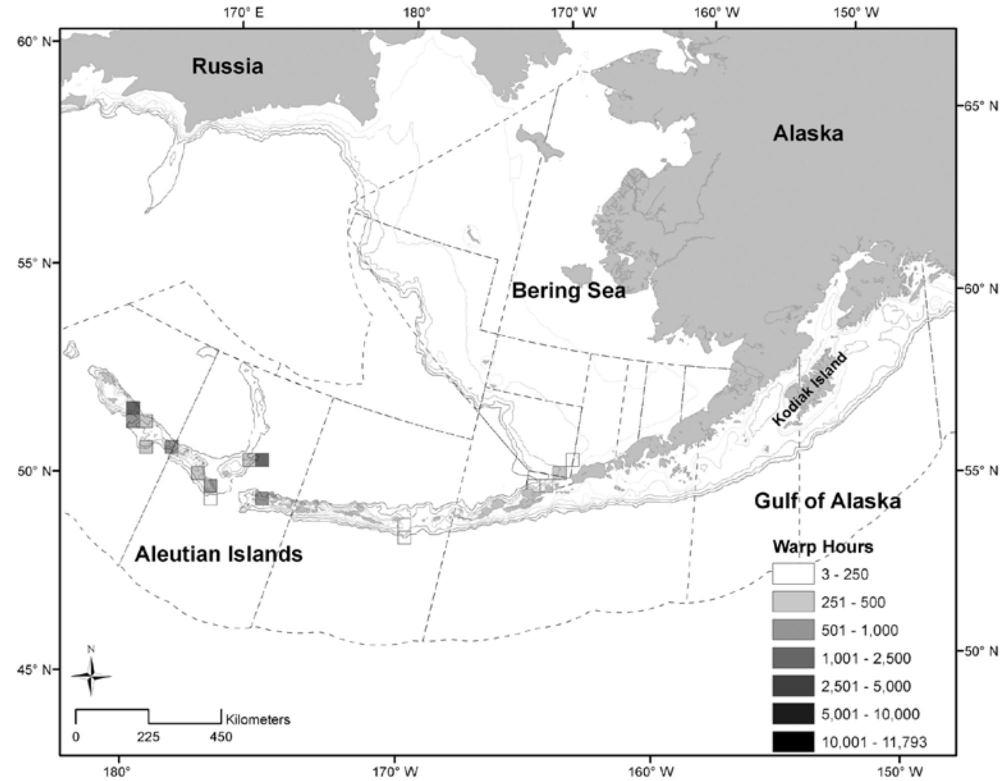


Figure 12. *Monthly warp effort (hours) during tows in the Atka mackerel fishery by year. *Indicates effort excluded when comprised of less than three vessels to protect confidentiality; 4%, 2% and 9% of total hours excluded for 2003, 2004 and 2005, respectively.*

A



B

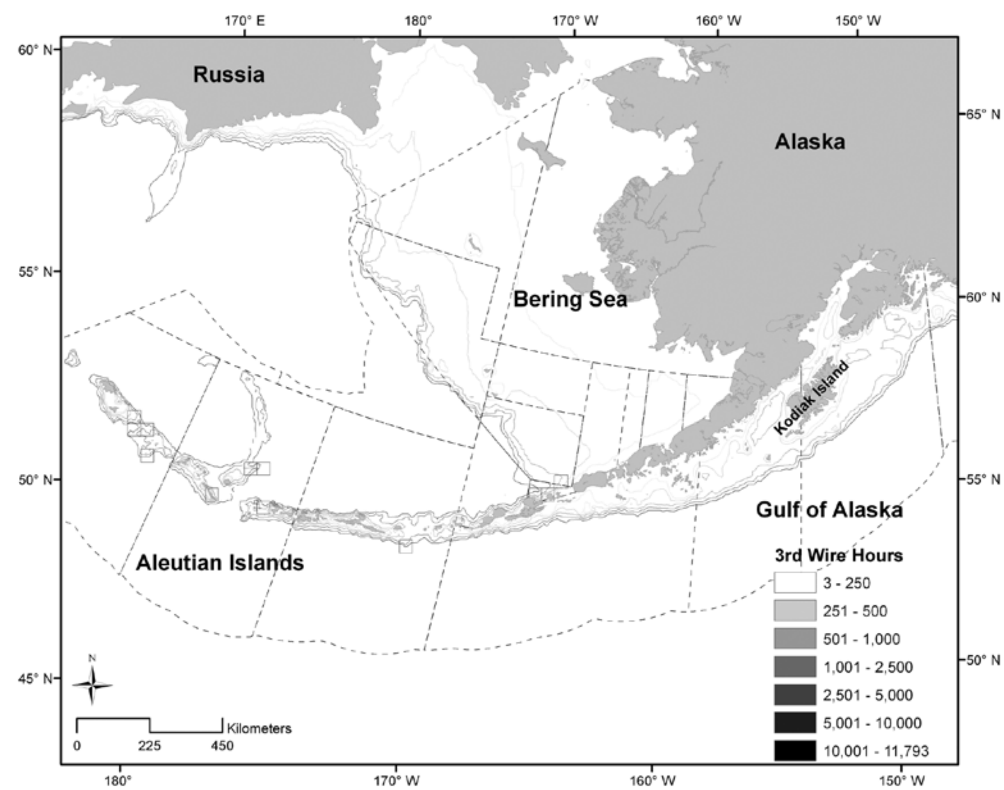


Figure 13. *Spatial distribution of 2005 Atka mackerel warp (A) and third wire (B) effort (hours) in the Bering Sea and Aleutian Islands. Dashed lines indicate U.S. exclusive economic zone and NMFS fisheries management areas. Effort is summarized within 40 km by 40 km grid cells and conforms to confidentiality requirements for presenting fishery observer data (three or more vessels fished within each cell displayed). More than half of the cells (52%) are displayed (95% of total observed Atka mackerel warp effort). Unobserved effort not extrapolated at the smaller spatial scale of maps.*

A

B

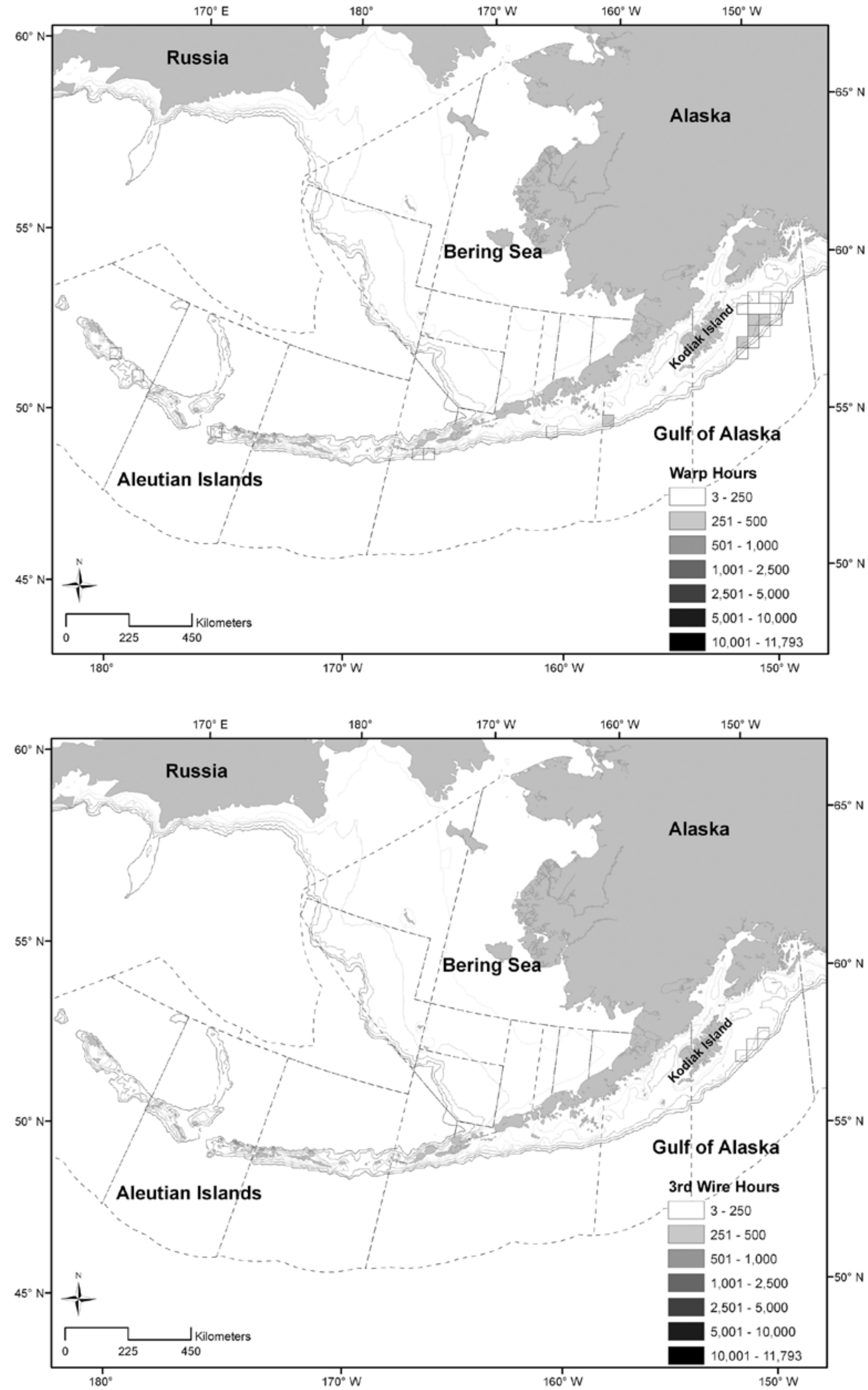


Figure 14. *Spatial distribution of 2005 rockfish warp (A) and third-wire (B) effort (hours) in the Aleutian Islands and Gulf of Alaska. Dashed lines indicate U.S. exclusive economic zone and NMFS fisheries management areas. Effort is summarized within 40 km by 40 km grid cells and conforms to confidentiality requirements for presenting fishery observer data (three or more vessels fished within each cell displayed). Less than half of the cells (26%) are displayed (61% of total observed rockfish warp effort). Unobserved effort not extrapolated at the smaller spatial scale of maps.*

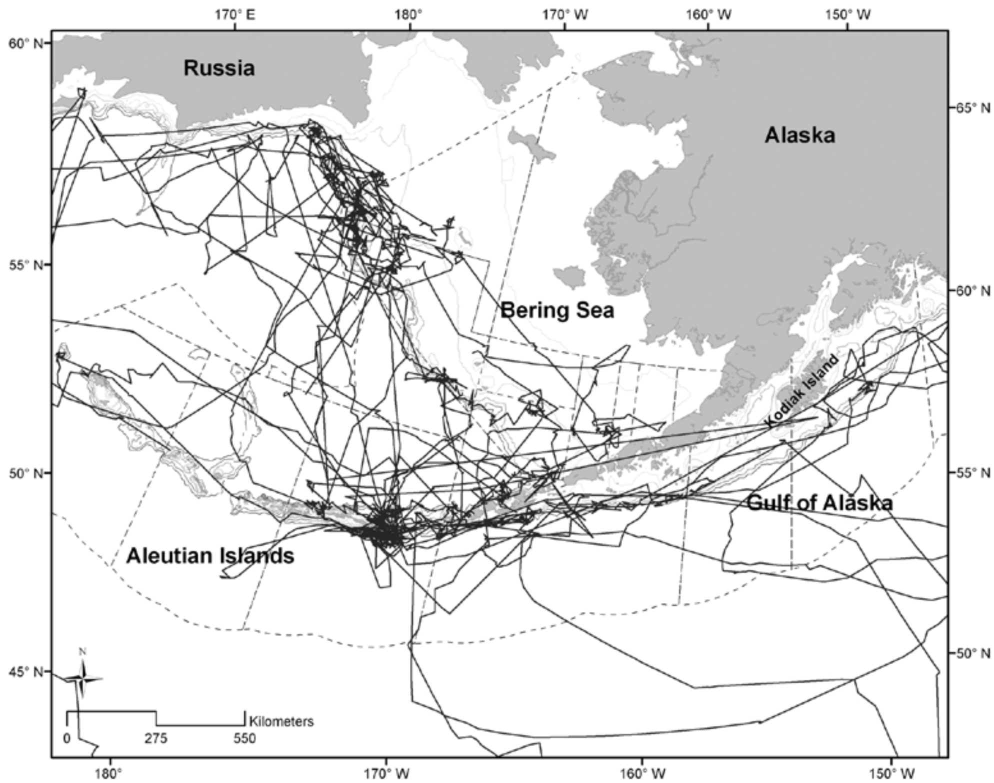


Figure 15. *Satellite tracking distribution of STAL captured in Seguam Pass, Aleutian Islands. Birds were tracked during August – November in 2003, 2005 and 2006. Satellite data displayed here and Figures 17-20 provided courtesy of R. Suryan, Oregon State University and G. Balogh, US FWS.*

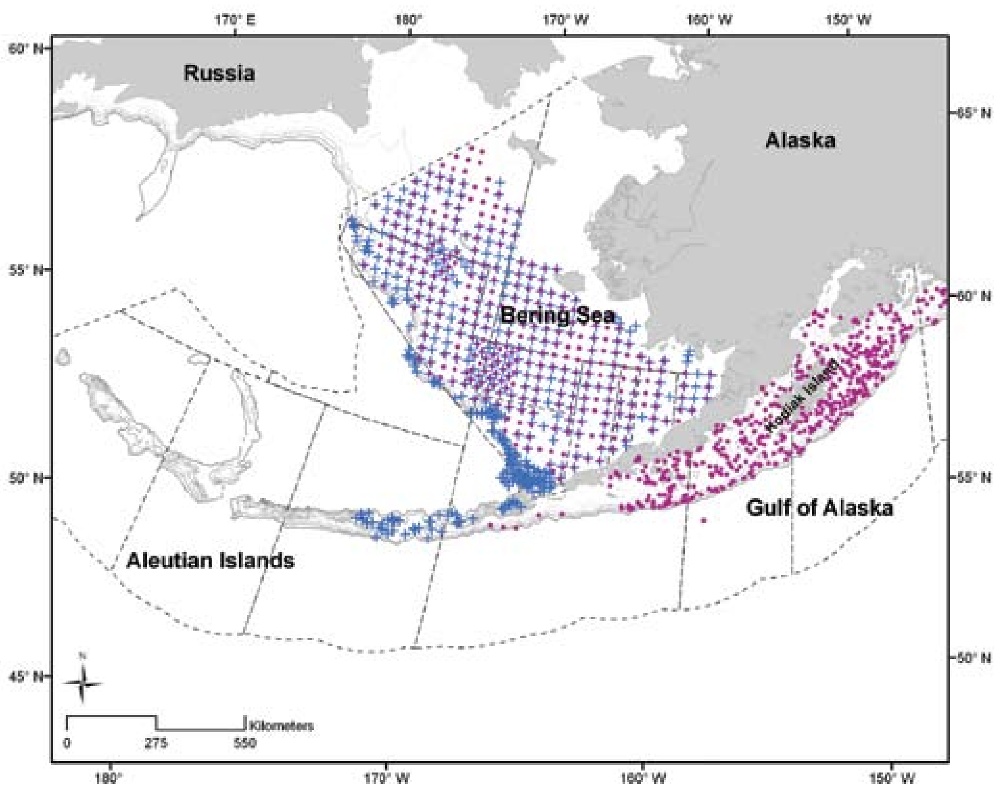
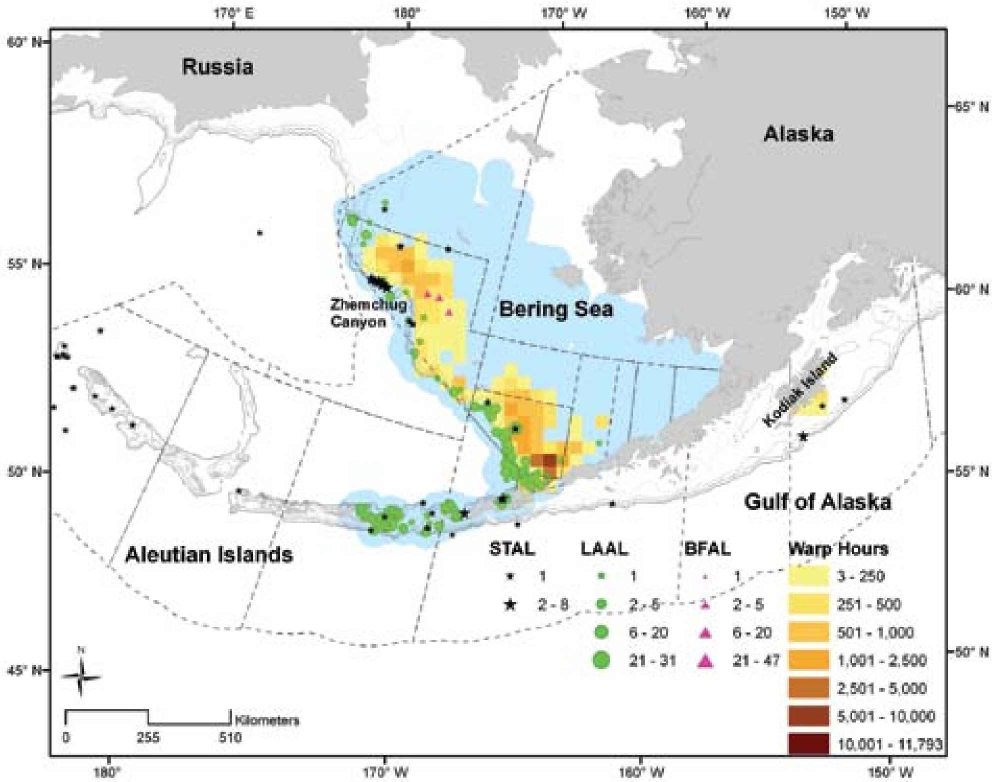


Figure 16. *Locations of NMFS stock assessment survey stations where seabird observations were made in June-August of 2004 (purple circle) and 2005 (blue cross).*

A



B

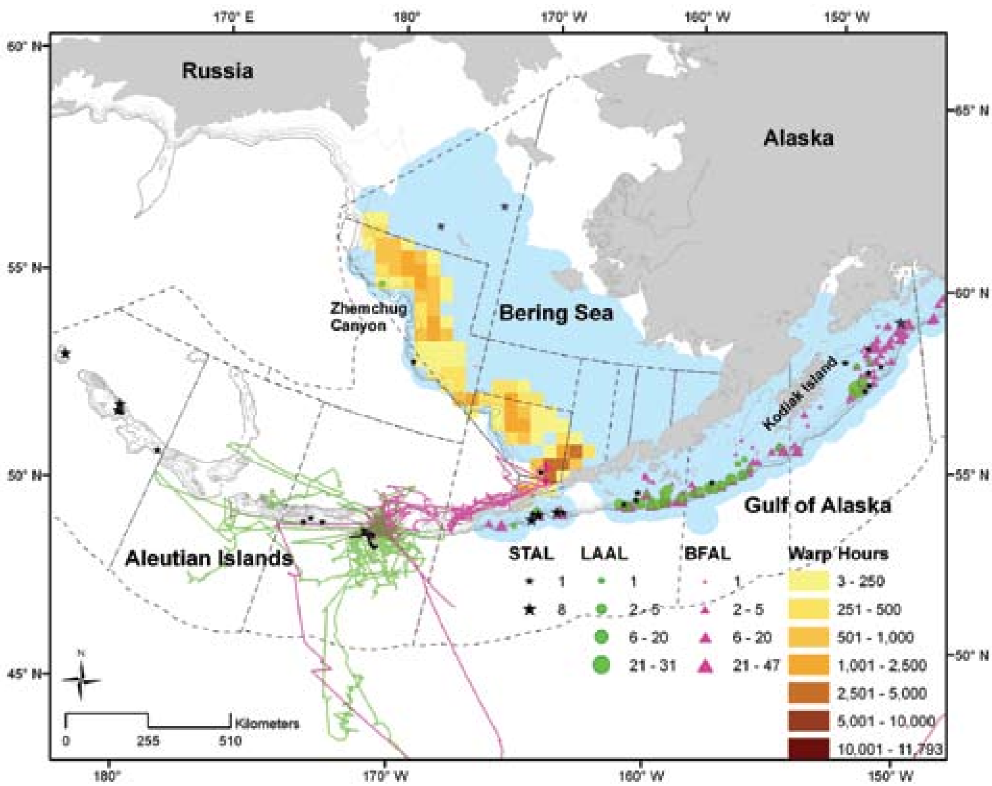


Figure 17. *Spatial distribution of observed pollock warp effort in June-August 2004 (A) and 2005 (B) with albatross sightings from NMFS stock assessment surveys, opportunistic short-tailed albatross (STAL) sightings and albatross satellite tracks (2005 only) during the same time periods. Satellite tracks of seven black-footed (BFAL; pink lines), nine Laysan (LAAL; green lines) and one STAL (black lines) captured in Seguam Pass, Aleutian Islands in August 2005. Locations plotted limited to August 2005. Light blue polygon represents area surveyed by NMFS stock assessment surveys. Dashed lines indicate U.S. exclusive economic zone and NMFS fisheries management areas. Effort is summarized within 40 km by 40 km grid cells and conforms to confidentiality requirements for presenting fishery observer data (three or more vessels fished within each cell displayed).*

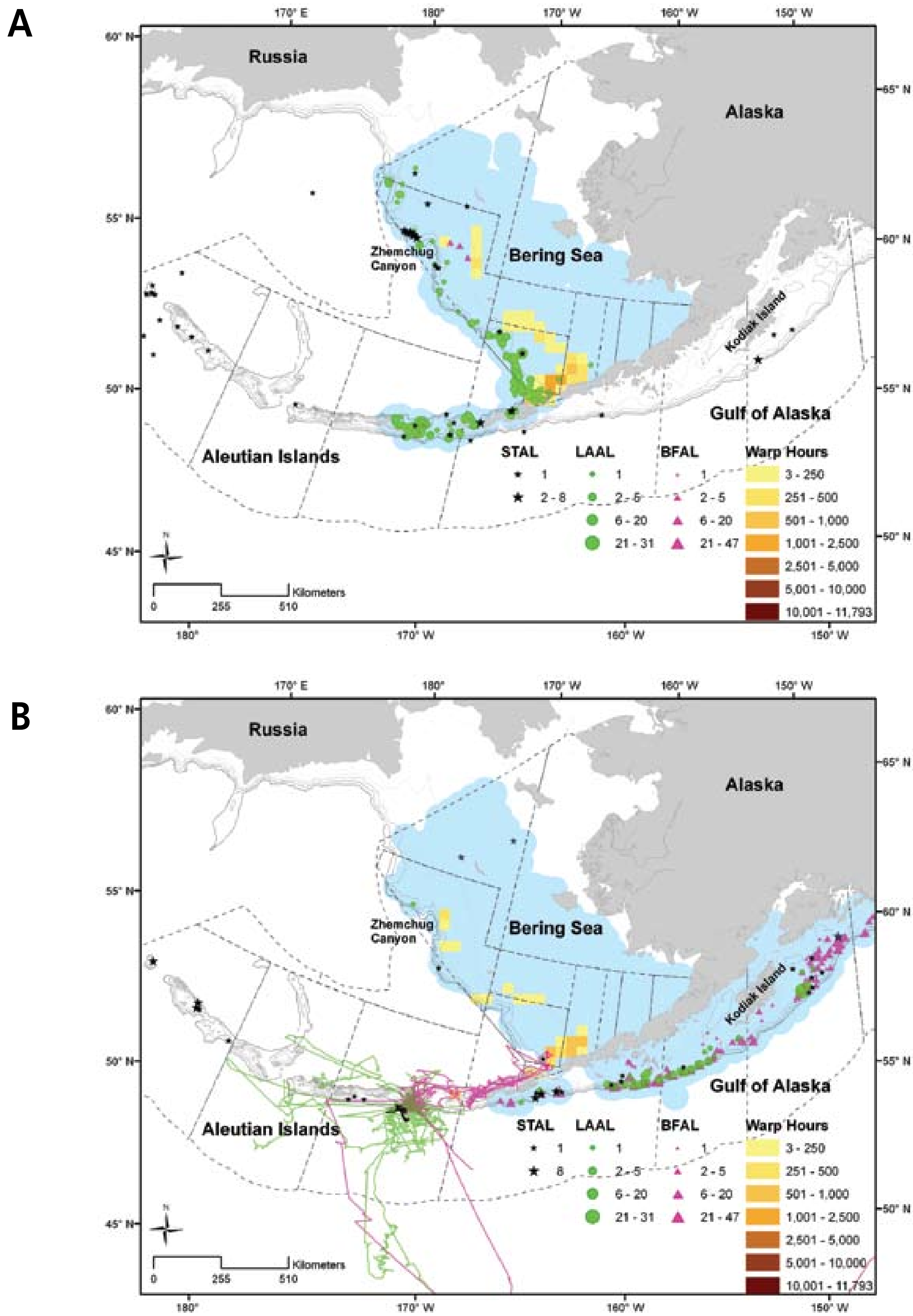


Figure 18. *Spatial distribution of observed cod warp effort in June-August 2004 (A) and 2005 (B) with albatross sightings from NMFS stock assessment surveys, opportunistic short-tailed albatross (STAL) sightings and albatross satellite tracks (2005 only) during the same time periods. Satellite tracks of seven black-footed (BFAL; pink lines), nine Laysan (LAAL; green lines) and one STAL (black lines) captured in Seguam Pass, Aleutian Islands in August 2005. Locations plotted limited to August 2005. Light blue polygon represents area surveyed by NMFS stock assessment surveys. Dashed lines indicate U.S. exclusive economic zone and NMFS fisheries management areas. Effort is summarized within 40 km by 40 km grid cells and conforms to confidentiality requirements for presenting fishery observer data (three or more vessels fished within each cell displayed).*

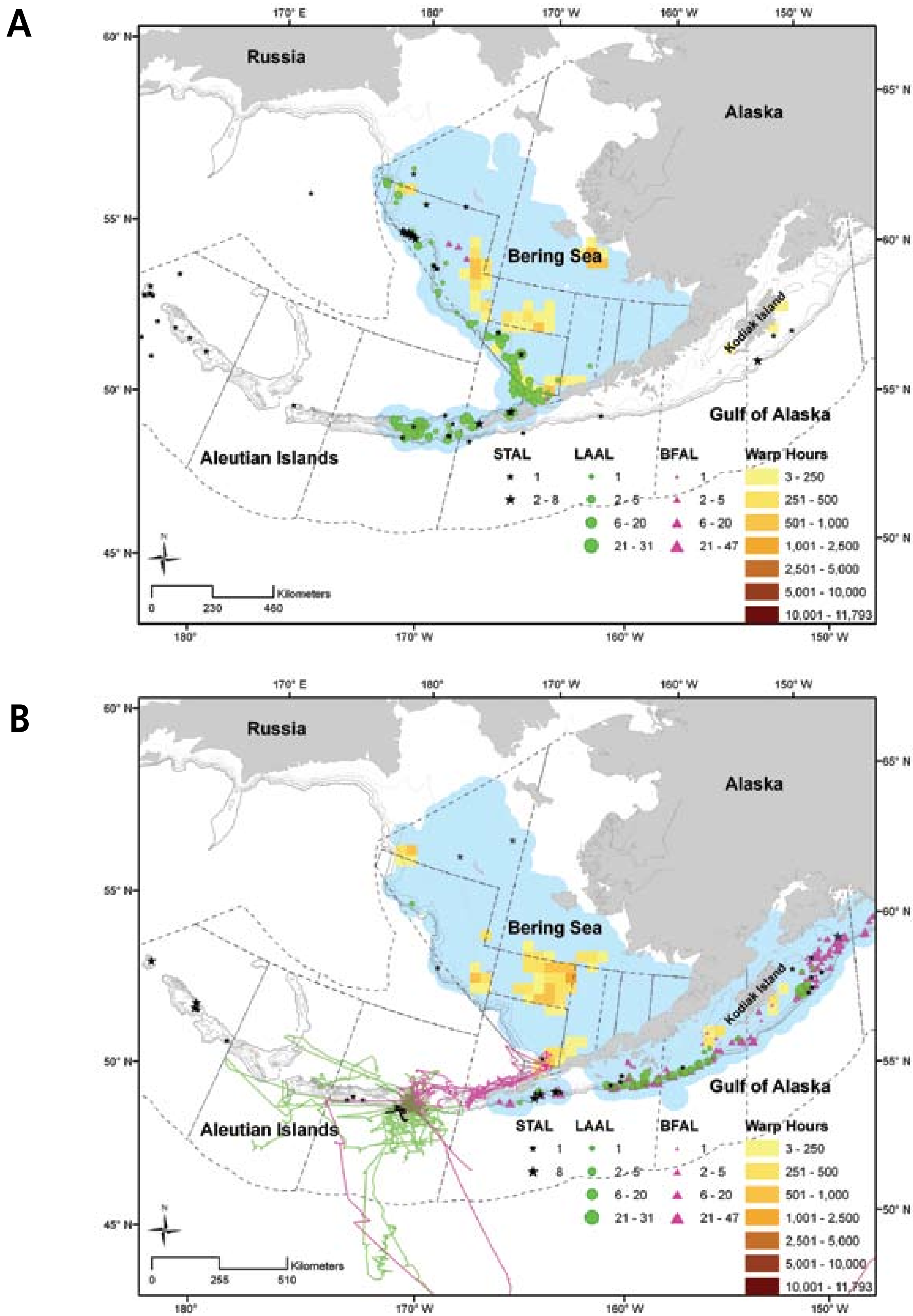


Figure 19. *Spatial distribution of observed flatfish warp effort in June-August 2004 (A) and 2005 (B) with albatross sightings from NMFS stock assessment surveys, opportunistic short-tailed albatross (STAL) sightings and albatross satellite tracks (2005 only) during the same time periods. Satellite tracks of seven black-footed (BFAL; pink lines), nine Laysan (LAAL; green lines) and one STAL (black lines) captured in Seguam Pass, Aleutian Islands in August 2005. Locations plotted limited to August 2005. Light blue polygon represents area surveyed by NMFS stock assessment surveys. Dashed lines indicate U.S. exclusive economic zone and NMFS fisheries management areas. Effort is summarized within 40 km by 40 km grid cells and conforms to confidentiality requirements for presenting fishery observer data (three or more vessels fished within each cell displayed).*

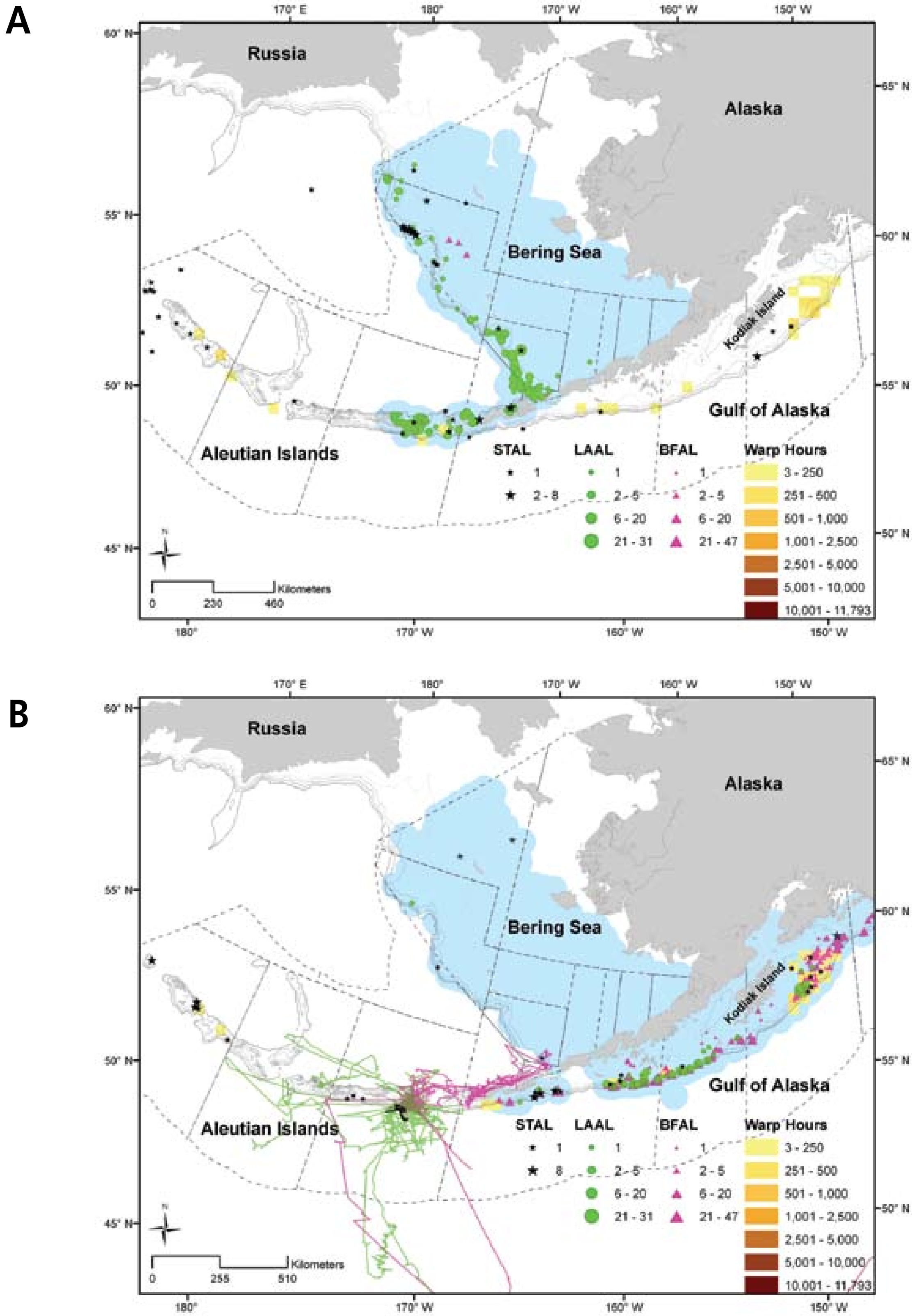


Figure 20. *Spatial distribution of observed rockfish warp effort in June-August 2004 (A) and 2005 (B) with albatross sightings from NMFS stock assessment surveys, opportunistic short-tailed albatross (STAL) sightings and albatross satellite tracks (2005 only) during the same time periods. Satellite tracks of seven black-footed (BFAL; pink lines), nine Laysan (LAAL; green lines) and one STAL (black lines) captured in Seguam Pass, Aleutian Islands in August 2005. Locations plotted limited to August 2005. Light blue polygon represents area surveyed by NMFS stock assessment surveys. Dashed lines indicate U.S. exclusive economic zone and NMFS fisheries management areas. Effort is summarized within 40 km by 40 km grid cells and conforms to confidentiality requirements for presenting fishery observer data (three or more vessels fished within each cell displayed).*

Warp and Third-Wire Effort: Flatfish

The number and type of vessels landing flatfish was consistent from year to year in all areas except in the GOA where the number of CPs operating in 2005 was half those in 2003 (Table 3). The catch of BS CPs increased by nearly 10,000 metric tons (11%) from 2003 to 2005 (Table 4), while warp and third-wire effort remained about the same (Tables 5-6). Both CPs and CV-S targeted flatfish in the GOA. GOA CV-S flatfish catch remained stable, whereas CP catch decreased (Table 4). GOA CV-S flatfish warp effort decreased by nearly 3,000 hours (29%) over this time period (Table 5), and third-wire effort was negligible (Table 6). GOA CP warp effort followed a declining pattern mirroring catch, whereas third-wire effort declined to nearly zero.

Like cod, flatfish is open in either the GOA or BS from January through October (Figure 2). Warp effort varied greatly by month, year and region, with no consistent peaks (Figure 10).

Flatfish effort was distributed across a larger depth range than any other fishery, due to the wider range of habitats preferred by the array of species targeted. Warp effort was most concentrated in the southeastern BS (north of the Alaska Peninsula), in the central BS (east and north of the Pribilof Islands) and east and southwest of Kodiak Island in the GOA (Figure 11). Third-wire effort had a similar pattern in the BS with negligible effort in the GOA.

More than half of the warp effort was at a cable extent less than 30 feet. A summary table for flatfish warp effort by cable distance is not shown due to the number of cells that would have been left blank to protect confidentiality.

Target Fisheries: Atka Mackerel

Atka mackerel is a relatively small target fishery across all regions; however, it constitutes the largest catch in the AI.

Fleet Description: Atka Mackerel

Atka mackerel is an exclusively CP fishery; no CVs targeted Atka mackerel. A more detailed description of the CPs that targeted Atka mackerel can be found in the flatfish section. Few CPs utilized a third wire while targeting Atka mackerel, and this varied by region (two of nine in AI; four of 10 in BS; Table 7). Vessels rarely shortwire (7% on average estimated by eight respondents), and responses regarding turns ranged from never to two (10 responses).

Warp and Third-Wire Effort: Atka Mackerel

Ten CPs consistently targeted Atka mackerel in the AI, although the number in the BS ranged from seven to 11 (Table 3). The bulk of effort (warp: 86%-93%) and catch (97%-99%) was in the AI. Both catch (Table 4) and warp effort during the tow (Table 5) increased slightly from 2003 to 2005 in both the BS and AI. Relative to fisheries already discussed, the Atka mackerel fishery accounts for a small proportion of total warp effort (1.9-2.7%; Table 5). Third-wire effort in this fishery was extremely low (< 35 hours in the BS and < 600 hours in the AI) and is less than 0.5 percent of overall third-wire effort (Table 6).

In general, the peak fishing months in the AI were September-October, with a smaller pulse in either January or February (Figure 12). AI fishing times are primarily determined by SSL conservation measures and EFH. BS effort peaked in August-September, May and July, and May-June for 2003, 2004 and 2005, respectively.

Atka mackerel were fished near many of the Aleutian Islands, including those that lie within the BS region. Higher concentrations of warp and third-wire effort occurred in the western and central AI areas (Figure 13).

Target Fisheries: Rockfish

Rockfish is a relatively small target fishery across all regions; however, the rockfish fishery constitutes the third-largest catch in the GOA.

Fleet Description: Rockfish

A more detailed description of the CPs and CV-S that targeted rockfish can be found in the flatfish and pollock sections, respectively. Very few vessels (three of 24 in GOA, zero of four in BS and zero of seven in AI) utilized a third wire while targeting rockfish (Table 7). CPs rarely shortwire (11% on average estimated by six respondents) and responses regarding turns ranged from never to three (10 responses).

Warp and Third-Wire Effort: Rockfish

The number of vessels targeting rockfish decreased from 50 to 38 over the 2003-2005 time period (Table 3), which was reflected in reductions of catch (Table 4). Note, however, that warp effort does not decrease by as much as might be expected in 2005, given fewer vessels (Table 5). Similar to the Atka mackerel fishery, the rockfish fishery contributes a small proportion of total warp effort (2.3-4%; Table 5). Third-wire effort is small (<600 hours) – less than 0.5 percent of overall third-wire effort (Table 6).

The bulk of rockfish warp effort occurred in July (94%-100%), when the season opened in all three regions (Figure 2), although there was a small amount of warp effort in August 2003 (4% for the year). The majority of catch and effort occurs in the GOA and AI (Tables 4-6). Effort was minimal in August-October due to reaching rockfish or other species allocations or economics (i.e., small allocations later in the season make targeting rockfish less desirable than other fisheries). The largest rockfish catches occurred in the AI (Table 4) with warp effort mirroring catch (Table 5; Figure 14A). No third-wire effort occurred in the AI and very little in the GOA (Table 6; Figure 14B).

Why Are Third Wires Used In Alaska Trawl Fisheries?

We solicited input from the fishing industry and scientific personnel experienced with third-wire systems and net sonar manufacturers to address potential benefits and discuss why these systems are used in Alaska.

All respondents agreed that third-wire systems provide significantly more benefits than wireless systems, especially for fishing vessels using large pelagic nets typical of the BSAI pollock fleet. Benefits of third-wire systems include the following:

- They provide an uninterrupted signal (including during course changes);
- They allow the transmission of a wider array of information between the net and the wheelhouse;
- They can accommodate future technological improvements to net monitoring systems (e.g., prohibited bycatch species

identification and current speed and direction), by their ability to transmit more information;

- They provide high quality and resolution data on fish schools relative to the opening of the net, allowing fishing to be more efficient (minimize tow hours to catch a specified quota, thereby increasing fuel efficiency);
- They provide data on the amount of fish in the net via tensiometers attached to meshes in the codend;
- They provide data on the morphology of the net opening and position of the net (footrope) relative to the sea floor;
- They assist with keeping the headrope/net centered during gear deployment and retrieval;
- They monitor the spread of the doors and where they are in relation to the horizontal;
- They provide a cable that can be used to help physically maintain the net opening at certain stages of a trawl. For example, during setting, hauling and turning, the lift provided by the third wire on the head rope unit prevents it from becoming entangled in the trawl. Wireless head rope units easily become tangled with the trawl during setting, hauling and turning. Once tangled, the gear must be hauled back aboard and cleared, a very difficult and time-consuming process. The resulting inefficiency could greatly increase the amount of time a net spends on the ocean surface, increasing the net's exposure to seabird interactions.

Although wireless systems are also capable of providing much of the data above, third-wire systems are deemed superior and considered indispensable to the Alaska pelagic pollock fleet. Banning third wires in Alaska trawl fisheries to protect seabirds could lead to economic inefficiencies such as an increase in fishing effort. These inefficiencies may increase fuel consumption as well as warp hours, which could in turn increase total seabird interactions with warps. Less control of the net could also increase bottom contact, aggravating habitat impact on benthic communities and potentially increasing the bycatch of other species.

Albatross Distribution, Overlap with Fisheries Effort and Seabird-Fishery Interactions

Albatross Distribution in Alaska

Short-tailed albatross: The STAL population is thought to have been in the millions prior to commercial exploitation (hunting for feathers and other body parts; USFWS 2005b). Approximately 2,300 STAL exist today, although the population is increasing at 6-8 percent per year (H. Hasegawa, pers. com. 2007). Due to the low but increasing population size, Alaska sightings have been rare but increased through 2004 (NPPSD 2005a). Most STAL adults remain near breeding colonies in Japan from October to late May or early June (USFWS 2005b). On average, 20 percent of the adults do not return to breed in any given year. STAL have been sighted in Alaskan waters during all months of the year, with peak sightings occurring from May to September (NPPSD 2005a). Six of seven STAL takes in the longline fishery occurred from 28 August to 1 October, a small proportion of the fishing year, suggesting that STAL are more vulnerable to takes during this time. Seabird point counts within a 50-meter radius area, once per station, were instituted on several longline fish stock assessment surveys (International Pacific Halibut Commission, NMFS AFSC and Alaska Department of Fish and Game starting in 2002; Melvin et al. 2006) and trawl and acoustic surveys (NMFS AFSC starting in 2004 and NMFS Northwest Fisheries Science Center starting in 2006). The bulk (93%) of longline, trawl and acoustic survey observations occurred during summer (Jun-Aug). During 2002-2004 longline surveys, STAL observation rates were highest in the western GOA and AI. In the BS, STAL sighting rates were low and not significantly different from other areas with no STAL sightings (Melvin et al. 2006). During 2004-2005 trawl and acoustic surveys, STAL sightings were rare but did occur in all three regions.

Breeding STAL adults were satellite tracked in 2006-2007 (R. Suryan, pers. comm.). During the chick-rearing period (February-April), adults foraged within 1,000 kilometers of the nesting colony outside Alaskan waters; however, during the post-breeding dispersal (May-August), most STAL traveled to Alaska waters, especially to the AI (*http://www.wfu.edu/biology/albatross/shorttail/shorttail3.htm*). All three albatross species were tracked during the non-breeding periods (August-November), using birds caught in Seguam Pass, Aleutian Islands; tagging location may influence their distribution pattern. STAL exhibited the widest latitudinal distribution compared to LAAL and BFAL, ranging from greater than 60 degrees north to 38 degrees north (Figure 15; Suryan et al. 2006).

Black-footed albatross: The BFAL breeding population is estimated at 58,000 pairs (2003-04; USFWS 2005a). Historic strip transect data from the 1970's and 1980's show BFAL occurred in Alaskan waters throughout the year, although in much lower density in the winter and early spring (NPPSD 2005b). Most BFAL adults return to breeding colonies in Hawaii and Japan from mid-October to late-June (Whittow 1993a). Although BFAL tend to be more ubiquitous across the North Pacific than LAAL (Gould et al. 1982), the majority of the BFAL sightings in the North Pacific Pelagic Seabird Database (NPPSD) occurred in the GOA. During 2002-2004 longline surveys, BFAL observation rates were highest in the western GOA through Oregon, compared to the BS and AI (Melvin et al. 2006). The trawl and acoustic surveys also had more BFAL sightings in the GOA.

In the late 1990's BFAL and LAAL were satellite tracked to determine foraging destinations during brooding (zero-18 days post-hatching) and chick rearing (>18 days post-hatching) periods. Fernandez et al. (2001) found both species remained nearly 1,000 kilometers closer to the breeding colony during the brooding period compared to the chick rearing periods. During chick-rearing, BFAL tended to travel to the coasts of California, Washington, Oregon and British Columbia. Using the same tracking data as Fernandez, Hyrenbach et al. (2002) reported substantial differences in habitat use between these two species; BFAL spent more time in the California Current (15°-12°C). The distribution of both species was also influenced by areas of elevated ocean productivity and prey aggregation. For non-breeding birds captured in Seguam Pass, BFAL either remained in the AI (2006) or traveled to the GOA or other parts of the eastern North Pacific (2005). Additional information on satellite tracking LAAL and BFAL from other areas can be found at the websites of the Albatross Conservation

Collaborative (*http://oikonos.org/projects/albatross.htm*) and Tracking of Pacific Pelagics (*http://www.topp.org/*).

Laysan albatross: The population of LAAL is the largest of the three North Pacific albatross species. The breeding population is estimated at 630,000 pairs (2003-04; USFWS 2005a). Most LAAL adults return to breeding colonies in Hawaii and Japan from early-November to mid-July (Whittow 1993b). Historic strip transect data from the 1970s and 1980s show LAAL occurred in Alaskan waters throughout the year, although at much lower density in the winter and early spring (NPPSD 2005b). Most of the LAAL sightings in the NPPSD were in the AI. Kuroda (1988) also sighted LAAL around AI from May through November while performing transects surveys from cargo ships crossing the North Pacific. More recently, the 2002-2004 longline surveys indicated that the highest LAAL observation rates were in the western GOA, AI and BS and were rare east and south of the western GOA (Melvin et al. 2006). The trawl and acoustic survey sightings also found more LAAL in the AI and along the BS shelf, although there was wide inter-annual variation.

Fernandez et al. (2001) found that many LAAL trips during the chick-rearing period were to the Aleutian Islands in 1998. In 1999, after a nearly complete breeding failure, tagged birds abandoned nests and were found between 35 degrees north and 45 degrees north. Hyrenbach et al. (2002) reported LAAL foraged in subarctic (<12ºC) and Transition Domains (15º-12ºC) during chick rearing. For non-breeding birds captured in Seguam Pass, LAAL remained in the AI and then dispersed to the central and western North Pacific (*http://www.wfu.edu/biology/albatross/shorttail/shorttail2.htm*).

Albatross Interactions with Alaska Trawl Fisheries

Few data exist on the extent of seabird interactions with Alaska trawl gear. Estimates of seabird mortality from interactions with Alaska trawl nets are derived from fishery observer sampling for species composition (NMFS 2006). In the years 2000 to 2004 best estimates included 313 birds (26 Laysan albatrosses) in AI, 647 birds (0 albatrosses) in the BS and 97 birds (0 albatrosses) in the GOA. We stress, however, that observer protocols were not designed to yield good estimates of seabird catch in trawl fisheries and account only for birds observed in the species composition sample. On CPs, observers are rarely required to be on deck as most of their sampling occurs in the factory. As noted earlier, fishery observers do not systematically collect data on seabird interactions with trawl cables in Alaska trawl fisheries; therefore, it is highly likely that estimates of seabird mortality generated from fishery observer data are underestimates.

Labunski and Kuletz (2004) summarized logbook notes collected by fisheries observers in the North Pacific Groundfish Observer Program from 1993-2003 compiled in the USFWS Observer Notes Database. Fishery observers are strongly encouraged to record seabird observations in their daily logbook outside of the normal species composition sampling, but notes are discretionary and not part of a sampling protocol. In 66 reported incidents, 215 seabirds were observed interacting with third wires. Most were fulmars (59 birds); 43 were reported killed, one flew off, and the fate of 15 was not recorded (USFWS Observer Notes Database). All 25 LAAL observed were reported as mortalities. These data on seabird-trawl cable interactions derived from observer notes provided the impetus for including the trawl fishery in the STAL BiOp.

Following the publication of the STAL BiOp, several studies were initiated to gather better information regarding how seabirds, especially STAL and other albatrosses, interact with or are affected by both trawl and longline fisheries. Most relevant to this discussion are: an assessment of potential population impacts on STAL due to several hypothetical scenarios of trawl mortality (Zador et al. In press); an evaluation of STAL overlap with various Alaska trawl sectors (Zador et al. In press); a study of the impact of discards on Alaska seabird populations (Edwards et al. In Prep.); feasibility testing of video monitoring to quantify seabird interactions with trawl cables (McElderry et al. 2004); and preemptive testing of seabird mitigation devices on Alaska pollock catcher-processors (Melvin et al. 2004 and Melvin et al. In prep.).

In 2002, a pilot study was initiated to test the feasibility of using video to monitor seabird interactions with Alaska trawl gear (McElderry et al. 2004). Seabird abundance and interaction rates and entanglements with third wires were determined for three pollock CV-S and two flatfish CPs. Seabirds attending CV-S vessels were few (< 4/ min) and birds tended to be absent during towing. CV-S third-wire strikes were exceedingly rare (0.009 birds per hour), and no birds were entangled. In contrast, seabird numbers attending flatfish CPs were high (defined as continuously present). CP third-wire collision rates were low (0.01 birds per hour) and entanglements did occur (0.04/hour). No albatrosses were seen in the course of the study. McElderry et al. (2004) also note that seabird abundance increased during poor weather. Given that this was a pilot study with limited observations in time and space, expanding these collision rates to total warp and third-wire effort is inappropriate.

In 2004, WSG and the Pollock Conservation Cooperative (PCC) initiated a pilot test of technologies to mitigate seabird cable strikes and developed and tested data collection protocols on BS pollock CPs. More intensive testing and sampling followed in the summer of 2005. In 2004, no albatrosses were seen, and no seabird mortalities were observed in 10 days of observations. In 36 days of observations in 2005, a single Laysan albatross brushed a third wire while in flight and was unharmed (Melvin et al. In Prep). Average third-wire “heavy” strike rates (those most likely to cause injury or mortality) were 45.2 strikes per hour during the tow and 66.2 strikes per hour while shortwiring. Interacting birds were primarily northern fulmars and short-tailed shearwaters (*Puffinus tenuirostris*). Heavy warp strikes during tows were substantially lower (13.7 collisions/hour) than third wire. Strike rates between this study and McElderry et al. (2004) are not comparable due to different time periods, target fisheries, vessel types and collision definitions.

Albatross Overlap with Alaska Trawl Fisheries

Our distribution maps of fishery effort are restricted to June-August of 2004 and 2005 to match the temporal scale of available seabird data (Figure 16). We plotted albatross satellite tracking data for August 2005 only to best match this same timeframe. We caution that overlapping effort with birds does not necessarily mean that interactions occur between trawl gear and seabirds in the area of overlap, and that satellite tracking may not be indicative of the distribution of any one species, given the limited number of birds tracked.

Overlap with Pollock

Nearly 37 percent of pollock effort occurred in the summer, concurrent with the fish stock assessment cruises. In 2004, albatross overlap with the pollock fishery was high (Figure 17A, Table 9) for the June-August period, especially LAAL (24/29 NMFS stations), along the southern BS shelf break, and STAL, northwest of Zhemchug Canyon (57° 30N, 175 ° 20W).

In 2005, albatross overlap of the pollock fishery was minimal. Only one LAAL was observed in the Bering Sea during the NMFS stock assessment surveys, and two satellite-tracked BFAL overlapped with the BS pollock fishery in the southeast BS (Figure 17B). A single STAL (one opportunistic sighting) overlapped the pollock fishery in 2005, although this could be an artifact of limited data (i.e., NPGOP observations are not included in the data set).

Overlap with Pacific Cod

Only 19 percent of cod effort occurred in the summer, concurrent with the fish stock assessment cruises. In 2004, there was moderate overlap of albatross with the cod fishery. Most albatross sightings were LAAL (13) in the southwestern BS, and one BFAL sighting occurred in a cod fishing area near Zhemchug Canyon (Figure 18A, Table 9). No STAL overlapped with the cod fishery in 2004.

In 2005, few albatrosses were observed in the Bering Sea during the NMFS stock assessment surveys, and none overlapped with the BS cod fishery (Figure 18B). However, three satellite-tracked BFAL overlapped the BS cod fishery. We note that most of the AI cod effort occurred in January and February (Figure 9), when the majority of breeding albatrosses are on colony and least abundant in Alaska. Little is known about the winter distribution of non-breeding albatross.

Overlap with Flatfish

Thirty-two percent of flatfish effort occurred in the summer, concurrent with the fish stock assessment cruises. In 2004, there was moderate albatross overlap with the flatfish fishery occurring along the BS shelf break (Figure 19A, Table 9). LAAL were the only species to overlap with the flatfish fishery. No albatrosses overlapped with the fishery in the GOA.

In 2005, overlap was minimal. Two BFAL overlapped the flatfish fishery in the GOA, and two satellite-tracked BFAL overlapped the flatfish fishery in the BS (Figure 19B). STAL overlap was minimal as well (one opportunistic sighting).

Overlap with Atka Mackerel

Less than 11 percent of Atka mackerel effort occurred in the summer, concurrent with the fish stock assessment cruises. Overlap with the Atka mackeral fishing was minimal in both years (Table 9). Atka mackerel effort peaked in September and October – the time when the numbers of all North Pacific albatrosses peak in Alaska waters (NPPSD 2005b). Seabird transect data from the 1970s and 1980s show a high abundance of LAAL in the AI Akta mackerel fishing areas (NPPSD 2005b). More information regarding the temporal abundance and distribution of albatrosses around the Aleutian Islands is required to precisely determine overlap with the Atka mackerel fishery. Several of the Atka mackerel fishing locations in the AI are known STAL hotspots (e.g., Ingenstrem Rocks; Piatt et al. 2006).

Overlap with Rockfish

Nearly 100 percent of rockfish effort occurred in the summer, concurrent with the fish stock assessment cruises. In 2004, STAL overlap was minimal (three STAL opportunistic sightings; Figure 20A, Table 9); however, survey data were not collected in the GOA for this year. In 2005, overlap with the rockfish fishery was high and occurred in both the AI and GOA (Figure 20B). Most albatrosses sighted were BFAL. Seabird data from the 1970s and 1980s show a high abundance of LAAL in the AI rockfish fishing areas and of BFAL in the GOA rockfish fishing areas (NPPSD 2005b). Several of the historic rockfish fishing locations in the AI (Clausen and Heifetz 2002) are also known STAL hotspots (Piatt et al. 2006).

Table 9. Overlap of albatrosses during June-August by fishery and year. AFSC includes the count of stations where albatrosses were sighted during the NMFS stock assessment surveys; STAL opp. includes the count of opportunistic sightings; Satellite is the number of individual birds that overlapped the fishery; nd=no data. Overlap categories defined as follows: None – 0; Minimal – 1-10; Moderate – 11-49; High - ≥ 50.

Target	Year	AFSC	STAL opp.	Satellite	Total	Overlap
Pollock	2004	29	21	nd	50	High
	2005	1	1	2	4	Minimal
Cod	2004	14	0	nd	14	Moderate
	2005	0	0	3	3	Minimal
Flatfish	2004	19	0	nd	19	Moderate
	2005	2	1	2	5	Minimal
Atka mackerel	2004	3	0	nd	3	Minimal
	2005	0	0	2	2	Minimal
Rockfish	2004	0	3	nd	3	Minimal
	2005	55	9	0	64	High

Discussion

Although the vast majority of warp and third-wire effort during 2003-2005 occurred in the pollock, cod and flatfish fisheries, overlap with albatrosses was minimal, except at the BS shelf break in 2004, when overlap with albatrosses was moderate to high. The Atka mackerel and rockfish fisheries, on the other hand, although accounting for relatively little of the total trawl effort, had relatively high overlap with albatrosses in summer and were concurrent with the final months of the albatross non-breeding season when albatross numbers peak in Alaska waters (NPPSD 2005b). It is important to note that seabird distribution data were limited or unavailable for some high-effort months in the pollock (February-March, September-October), cod (February), and Atka mackerel (September-October) fisheries. Also, the spatial scope of fishery surveys and, therefore, seabird surveys differed in 2004 and 2005.

The estimates of warp and third-wire effort in this report are minimum values for the tow period only. Estimates of trawl cable effort for the entire trawl (set through haul) could be significantly improved by:

- Collecting more specific and quantitative information on the extent of third-wire use from the entire fleet;
- Ensuring that tow duration data collected by fishery observers and captains does not include the shortwire period; and
- Collecting more detailed information regarding duration of other trawl periods (set, shortwire, haul).

In addition, the lack of a direct link between NPGOP tows and CAS weekly catch limited our ability to utilize catch data when observer data were unavailable. A consistent link between the CAS and NPGOP databases would allow unobserved effort to be extrapolated from landing data.

Alaska fisheries are not static, and cable effort is influenced by a multitude of factors. Proposed management measures have the potential to prompt changes in several fisheries in the near future, which are very likely to affect both the temporal and spatial distributions of trawl effort. For instance, Amendment 80 to the BSAI Fishery Management Plan (FMP) will allow the CPs targeting flatfish, Atka mackerel, Pacific cod and AI Pacific Ocean perch (*Sebastes alutus*) to form fishing cooperatives. These new arrangements would allow the vessels to have more flexibility to fish their individual allocations throughout the year. It is unlikely that the timing of the Atka mackerel fishery will change due to existing SSL conservation measures; however, the timing of other target fisheries will become much more flexible and less predictable (L. Swanson, pers. com). Amendment 80 may have other unforeseen impacts. For example, increased shortwiring may occur in fisheries that previously had none, due to a requirement to not mix tows in the holds. Amendment 68 to the GOA FMP, implemented in 2007, could influence the GOA rockfish fishery (i.e., the temporal extent is likely to shift to a wider time window as the fishery is now open from May 1-Nov. 15, instead of the July 1 opening in the past). The quantity of offal discarded could also change under Amendment 68, due to increased retention requirements. Salmon hotspot closures in the pollock fishery may change the pollock effort distribution from year to year. Finally, changes in quota of one target species (e.g., a reduction in BS pollock quota) may allow for increased quota of another target species, which in turn could change the distribution of overall cable effort in the Alaska trawl fishery.

Priority Areas for Future Seabird Interaction Data Collection – Informing Future Mitigation Research

Overlap of seabirds with fishing effort does not necessarily mean that seabirds, albatrosses in particular, are interacting with trawl gear (Melvin et al. In prep.). Nor can we rule out the possibility that high-effort fisheries with minimal albatross overlap could have adverse effects, given their scale. Much more information is required regarding temporal and spatial distribution of albatrosses throughout the year. The essential first step is to quantify the collision rates and mortality rates of albatrosses interacting with trawl cables (warp or third wire) in fisheries with moderate or high overlap with albatrosses, with specific attention to vessel type and cable aerial extent.

Based on this analysis, we recommend that future efforts to determine the extent of interactions with trawl gear in the federal fisheries off Alaska focus on the rockfish in the GOA, Atka mackerel in the BSAI from May to October, and possibly cod in the AI in winter, due to previously observed interactions in this fishery (USFWS Observer Notes Database 2004). If few interactions are found in these fisheries with high overlap with albatrosses, we feel it would be reasonable to conclude that Alaska trawl gear poses no significant risk to albatrosses (see also Zador et al. In Press).

If high rates of interactions and mortalities are found in these fisheries, or if it seems likely that these fisheries may be interacting with ESA-listed species, mitigation development and testing should take place in the fisheries with the highest interaction rates. High interaction rates in fisheries with moderate to high albatross overlap would also justify a closer look at albatross cable collision rates in high-effort, minimal overlap fisheries and, based on the outcome of these observations, at the need for mitigation.

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Appendix A

Industry Questionnaire

Trawl Effort Characterization – Background

Recent studies show that seabird strikes on trawl cables can result in significant mortality of large winged seabirds such as albatrosses. Third wire or net sonde cables have been banned in many Southern Hemisphere fisheries beginning in 1991. More recently, strikes on warp cables have been shown to kill albatrosses in large numbers. These observations have led to questions regarding the extent to which seabird cable strikes are a conservation issue in Alaska trawl fisheries. The short-tailed albatross biological opinion (USFWS 2003) was extended to include Alaska trawl fisheries in 2003 based on reports from other fisheries and reports of seabird mortalities on third-wire cables. The Biological Opinion sets an incidental take limit of two short-tails over a five year period and requires NMFS to submit a summary report estimating total third-wire effort in Alaska groundfish fisheries.

Washington Sea Grant is actively developing warp strike mitigation with the Bering Sea pollock catcher-processor fleet in collaboration with the Pollock Conservation Collaborative. Recently we accepted a contract to gather the appropriate information and complete an analysis estimating both warp and third-wire effort (defined as time deployed) across the entire Alaska trawl fleet. In order to complete this task we intend to collect information at the individual vessel level that we believe is relevant. Our objective is to determine the extent to which the cable strike seabird mortality issue is relevant to the Alaska fleet and to inform our efforts to develop appropriate mitigation technologies. Data sources will include the North Pacific Groundfish Observer Program database, the Alaska Region's catch accounting database and information collected directly from the fishing industry via industry associations. The following is a brief explanation of the information we ask for on the accompanying form:

Fishery: These are generalized into 10 broad categories: BS Poll; GOA Poll; BS cod; AI cod; GOA cod; Atka mackerel; AI Rockfish; GOA Rockfish; BSAI Flatfish; GOA Flatfish. Enter a separate row for each fishery a vessel participates in. We plan to summarize the information in each column by fishery and vessel type.

Warps: Important variables are warp diameter and material, distance astern that cable enters water and height and location of the warp block. Seabirds drowned on warps can become entangled on warp splices.

Third Wire, wireless net monitoring: These questions will allow us to describe the extent to which different types of net monitoring systems are used by fishery.

Shortwire: Shortwiring is when the codend is full and doors are brought to the surface while underway. This excludes turns. This is probably most relevant to catcher-processing vessels and catcher vessels delivering codends. Seabird interactions with a third wire may differ during a shortwire compared to a tow.

Turns: A turn is defined as a change of course exceeding 45 degrees. Seabird interaction rates may change during turns.

Discards: Frequency, quantity and type of discard may influence the types of birds attracted to a given vessel.

Delivery location: In order to utilize the Region's catch accounting system, we need to know which vessels deliver to the various processing facilities (both inshore and offshore).

For each vessel/fishery combination we requested the following information in a spreadsheet format:

Warps
- Diameter (include units if not inches)
- Materials
- Splices present on warps (other than on ends)? Yes/No
- Average distance astern warps enter water (see diagram #1): <10 ft (3m); 10-20 ft (3-6.1m); 20-30 ft (6.1-9.1m); 30-60 ft (9.1-18.3m); or >60ft (>18.3m)
- Position of warp blocks relative to stern. Enter letter of closest position in diagram #2: A, B, C, or D
- Height of warp blocks relative to water: 5-10 ft (1.5-3m); 10-15 ft (3-4.6m); 15-20 ft (4.6-6.1m); 20-25 ft (6.1-7.6m); >25 ft (>7.6m)

Third Wire
- What percent of hauls do you use third wire?
- Third-wire diameter (inlcude units if not inches)
- Third-wire material (e.g., plastic, steel)
- Average distance astern third wire enters water during tow (diagram #1): <25 ft (7.6m); 25-50 ft (7.6-15.2m); 50-75 ft (15.2-22.9m); 75-100 ft (22.9-30.5m); >100 ft (>30.5m)
- Position of third-wire block relative to stern. Enter letter of closest position in diagram #2 (D, E, or F)
- Height of third-wire block relative to water: <10 ft (<3m); 10-15 ft (3-4.6m); 15-20 ft (4.6-6.1m); 20-25 ft (6.1-7.6m); 25-30 ft (7.6-9.1m); >30 ft (>9.1m)

Paravane
- What percent of hauls do you use a wireless system with paravane?
- Distance outboard that paravane is deployed: <10 ft or >10 ft
- Does paravane enter discharge plume? Yes/No

Hull-mounted system
- What percent of hauls do you use wireless system with a hull-mounted receiver?

Shortwires
- What percent of tows are shortwired (exclude turns)? Record by season (A,B), if different.

Turns
- Frequency of turns per tow under normal conditions: Never, 1, 2, 3, 4+

CP – Products (check all that apply):
- Whole, H&G, Surimi, Fillets, Mince, Fishmeal, Fish Oil

CVs - Discarding
- What percent of tows are whole fish discarded?
- When discard whole fish, what proportion of catch (wt) is typically discarded?
- What percent of tows is offal discarded? Includes processed fish parts such as heads, guts, skin.

- When discard offal, what proportion of catch (wt) is typically processed in this manner?
- Do you macerate fish/offal prior to discharge (excl. prohibs)? Yes/No
- Do dicards typically occur while towing? Yes/No

CVs – Delivery location

- Do you deliver shoreside (land or anchored floater)? Yes/No List plants.
- Do you deliver to a CP or

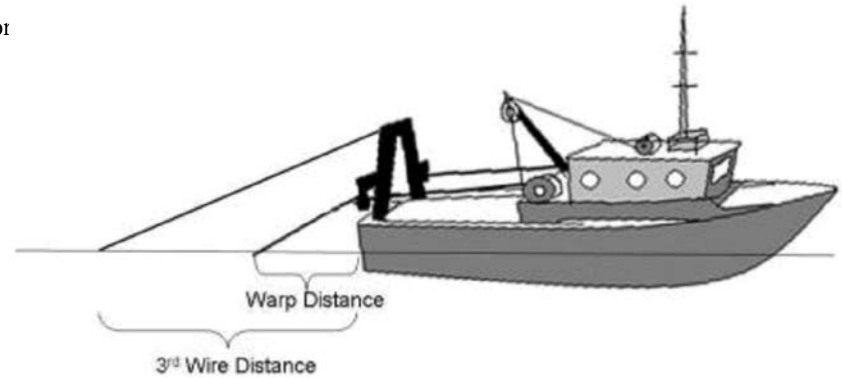


Diagram of cable distance and height

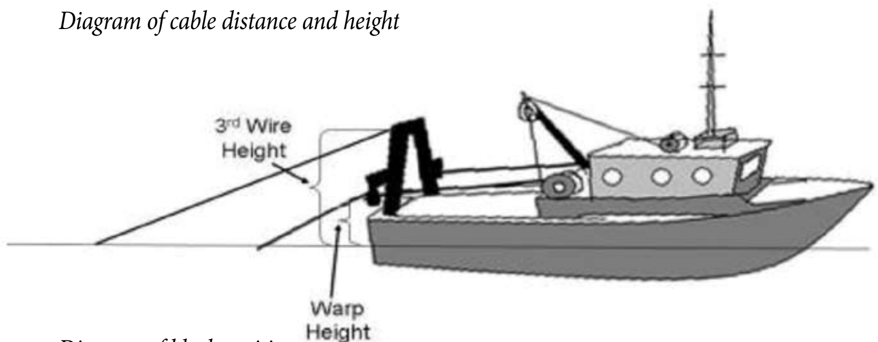
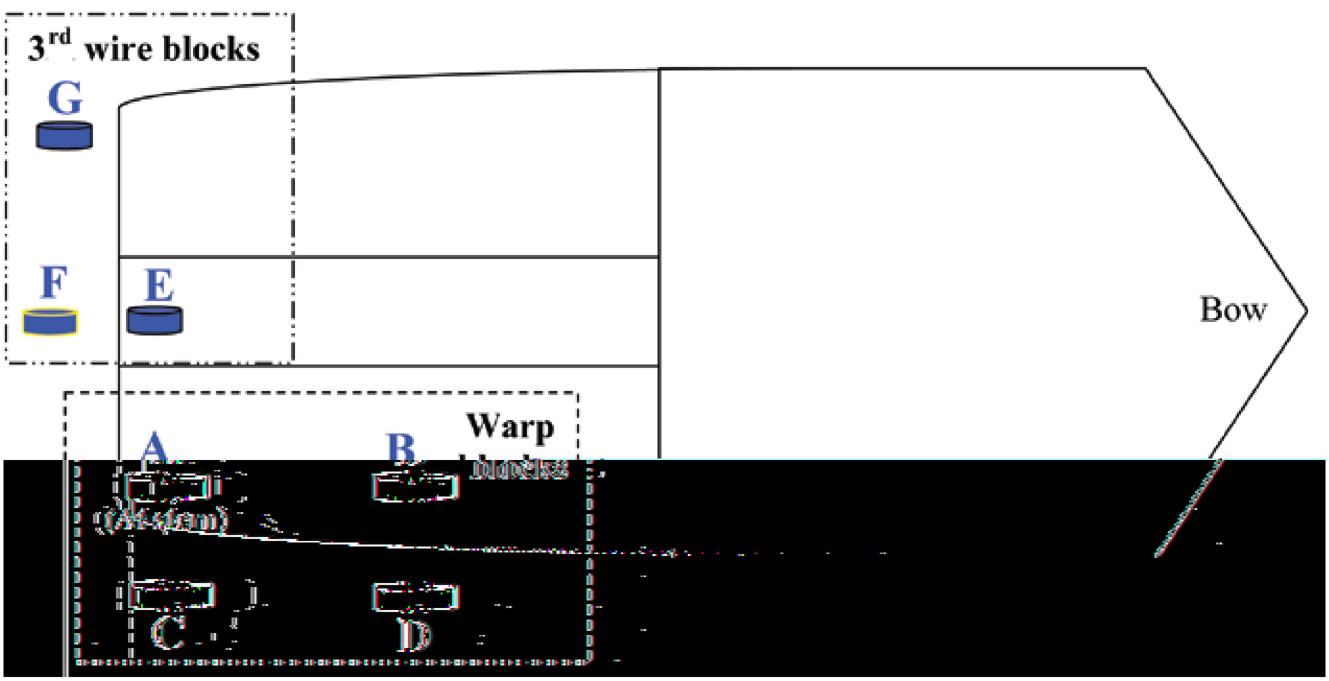


Diagram of block positions



Appendix B

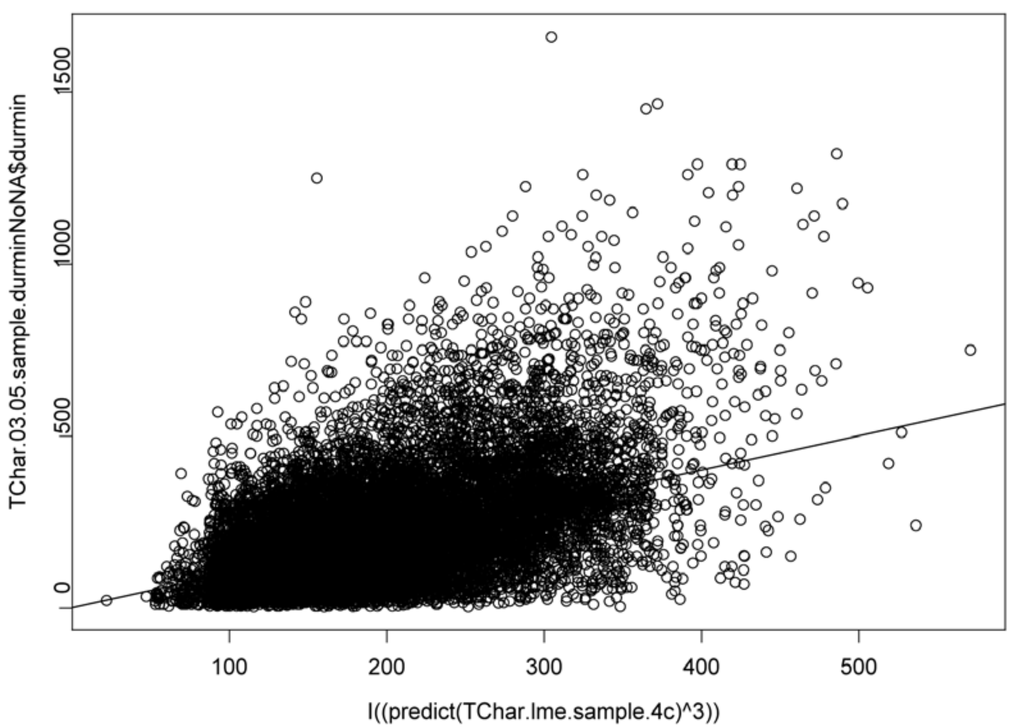
LME Model Output for Estimating Missing Tow Duration

```
> TChar.lme.full <- lme(durmin.crt ~ otc + year + months + area.f + targetr +
   vtype.f, data = TChar.03.05.group, random =  ~ 1 | vname/targetr, method = "ML",
   na.action = na.omit)

> anova(TChar.lme.full)

            numDF denDF  F-value p-value
(Intercept)     1 99508 26645.40  <.0001
        otc     1 99508   281.22  <.0001
       year     2 99508    19.04  <.0001
     months    11 99508   452.64  <.0001
     area.f    17 99508   122.17  <.0001
    targetr     6   264    21.98  <.0001
    vtype.f     2 99508    14.63  <.0001

#plot predicted vs actual duration (minutes) for final model using subsample of data
(n=19,551)
> plot(TChar.03.05.sample.durminNoNA$durmin ~ I((predict(TChar.lme.sample.4c)^3)))
abline(1,1)
```



```
> summary(TChar.lme.full)

Linear mixed-effects model fit by maximum
    likelihood
 Data: TChar.03.05.group
       AIC      BIC    logLik
  311782.7 312191.7 -155848.3

Random effects:
 Formula:  ~ 1 | vname
        (Intercept)
StdDev:   0.2854037

 Formula:  ~ 1 | targetr %in% vname
        (Intercept) Residual
StdDev:   0.5029326 1.142644

Fixed effects: durmin.crt ~ otc + year + months + area.f
   + targetr + vtype.f
                Value Std.Error    DF   t-value p-value
(Intercept)  5.476385 0.0841616 99508  65.06984  <.0001
        otc  0.003141 0.0001422 99508  22.09337  <.0001
      year1  0.015180 0.0045240 99508   3.35543  0.0008
      year2  0.028694 0.0026967 99508  10.64039  <.0001
    months1  0.146282 0.0089829 99508  16.28444  <.0001
    months2  0.020256 0.0051702 99508   3.91791  0.0001
    months3  0.067945 0.0045613 99508  14.89589  <.0001
    months4  0.031411 0.0039039 99508   8.04597  <.0001
    months5  0.025505 0.0028062 99508   9.08861  <.0001
    months6  0.029670 0.0018819 99508  15.76570  <.0001
    months7  0.044142 0.0014939 99508  29.54711  <.0001
    months8  0.058667 0.0015453 99508  37.96556  <.0001
    months9  0.089515 0.0019062 99508  46.96006  <.0001
   months10  0.000873 0.0048640 99508   0.17957  0.8575
   months11  0.063228 0.0360878 99508   1.75206  0.0798
    area.f1 -0.008084 0.0081965 99508  -0.98628  0.3240
    area.f2 -0.028945 0.0074677 99508  -3.87608  0.0001
    area.f3  0.040596 0.0064633 99508   6.28102  <.0001
    area.f4  0.061845 0.0029020 99508  21.31104  <.0001
    area.f5 -0.241808 0.1351616 99508  -1.78903  0.0736
    area.f6  0.023730 0.0195905 99508   1.21132  0.2258
    area.f7 -0.007259 0.0145683 99508  -0.49825  0.6183
    area.f8  0.003131 0.0152472 99508   0.20538  0.8373
   area.f9  0.007936 0.0093839 99508   0.84565  0.3977
   area.f10  0.001562 0.0080281 99508   0.19458  0.8457
   area.f11  0.006197 0.0072942 99508   0.84958  0.3956
   area.f12  0.000872 0.0063626 99508   0.13698  0.8910
   area.f13 -0.003148 0.0050581 99508  -0.62238  0.5337
   area.f14 -0.006890 0.0043430 99508  -1.58635  0.1127
   area.f15 -0.030814 0.0040484 99508  -7.61136  <.0001
   area.f16  0.026825 0.0105692 99508   2.53801  0.0112
   area.f17 -0.013333 0.0117708 99508  -1.13267  0.2574
   targetr1  0.516999 0.0721311   264   7.16748  <.0001
   targetr2  0.140623 0.0326296   264   4.30969  <.0001
   targetr3  0.043519 0.0436138   264   0.99783  0.3193
   targetr4  0.018923 0.0163698   264   1.15596  0.2487
   targetr5 -0.074258 0.0154147   264  -4.81733  <.0001
   targetr6 -0.086428 0.0339086   264  -2.54886  0.0114
   vtype.f1  0.136203 0.0428443 99508   3.17903  0.0015
   vtype.f2  0.130536 0.0242171 99508   5.39026  <.0001

Standardized Within-Group Residuals:
      Min         Q1        Med         Q3      Max
 -4.79339 -0.5670877 0.06685832 0.5928397 4.960238

Number of Observations: 99986
Number of Groups:
 vname targetr %in% vname
   175               445

> intervals(TChar.lme.full)

Approximate 95% confidence intervals

 Fixed effects:
                  lower          est.          upper
(Intercept)  5.311461997  5.4763848068  5.641307617
        otc  0.002862437  0.0031410342  0.003419632
      year1  0.006314802  0.0151800920  0.024045382
      year2  0.023409486  0.0286939235  0.033978361
    months1  0.128678728  0.1462815967  0.163884466
    months2  0.010124815  0.0202562489  0.030387683
    months3  0.059006558  0.0679448999  0.076883242
    months4  0.023760834  0.0314109717  0.039061110
    months5  0.020005647  0.0255047246  0.031003802
    months6  0.025981883  0.0296696715  0.033357460
    months7  0.041214198  0.0441417239  0.047069250
    months8  0.055639256  0.0586673781  0.061695500
    months9  0.085779542  0.0895149090  0.093250276
   months10 -0.008658042  0.0008734221  0.010404886
   months11 -0.007489354  0.0632282011  0.133945756
    area.f1 -0.024145828 -0.0080840443  0.007977739
    area.f2 -0.043579091 -0.0289454245 -0.014311758
    area.f3  0.027930764  0.0405962708  0.053261778
    area.f4  0.056158641  0.0618454646  0.067532288
    area.f5 -0.506670475 -0.2418083858  0.023053703
    area.f6 -0.014659209  0.0237303361  0.062119881
    area.f7 -0.035806650 -0.0072586184  0.021289413
    area.f8 -0.026746859  0.0031314890  0.033009837
    area.f9 -0.010453179  0.0079355598  0.026324299
   area.f10 -0.014169635  0.0015621020  0.017293839
   area.f11 -0.008096635  0.0061969507  0.020490537
   area.f12 -0.011596594  0.0008715377  0.013339670
   area.f13 -0.013059779 -0.0031480395  0.006763700
   area.f14 -0.015400134 -0.0068895632  0.001621007
   area.f15 -0.038746670 -0.0308135183 -0.022880367
   area.f16  0.006113332  0.0268246555  0.047535979
   area.f17 -0.036398591 -0.0133325083  0.009733574
   targetr1  0.375001594  0.5169986726  0.658995751
   targetr2  0.076388856  0.1406234414  0.204858027
   targetr3 -0.042338699  0.0435192488  0.129377197
   targetr4 -0.013302646  0.0189227967  0.051148239
   targetr5 -0.104603291 -0.0742579019 -0.043912513
   targetr6 -0.153180473 -0.0864281756 -0.019675879
   vtype.f1  0.052245574  0.1362030451  0.220160516
   vtype.f2  0.083080708  0.1305363869  0.177992066

 Random Effects:
  Level: vname
                    lower      est.     upper
sd((Intercept)) 0.2124508 0.2854037 0.3834077
  Level: targetr
                   lower      est.     upper
sd((Intercept)) 0.451473 0.5029326 0.5602577

 Within-group standard error:
    lower     est.    upper
 1.137631 1.142644 1.147679
```

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