Chum salmon buried in age-0 pollock. Photo by Kris Cieciel.

Connecting Independent Research Surveys of Bering Sea Salmon Populations to Chum Salmon Bycatch in Bering Sea Groundfish Fisheries

By Jim Murphy and Ed Farley

Introduction

Although chum salmon bycatch has historically remained at low levels relative to their biomass in the Bering Sea, recent increases in chum salmon bycatch have generated concern over bycatch impacts on Alaskan salmon stocks and the effectiveness of regulatory measures used to control bycatch in the groundfish fisheries. Member nations of the North Pacific Anadromous Fish Commission (Canada, Japan, Russia, South Korea, and the United States) developed the Bering-Aleutian Salmon International Survey (BASIS) in 2002 as an international cooperative research program designed to address concerns over the distribution, growth, and survival of salmon in the Bering Sea. By connecting information collected during BASIS research surveys to bycatch, we identify how size, foraging behavior, and foraging hotspots of chum salmon are important controlling factors of bycatch and bycatch potential in Bering Sea groundfish fisheries.

The Bering Sea walleye pollock (*Theragra chalcogramma*) fishery is the largest commercial fishery by weight within the United States. The walleye pollock fishery occurs during two distinct periods throughout the year, with the 'A' season fishery during late January to the end of March and the 'B' season fishery from mid-June to the end of October. The relative bycatch during the fishery is low, averaging approximately 1.2% of total removals by weight, compared to the estimated bycatch of 11% for all Alaska fisheries and the average nationwide bycatch estimates that approach 22% by weight. Of the 1.2% bycatch by weight in the Bering Sea pollock fishery, 24% is attributed to jellyfish while 64% consists of other quota-managed target groundfish species. A smaller portion consists of Pacific salmon (*Oncorhynchus* spp.)—mainly chum (*O. keta*) and Chinook salmon (*O. tshawytscha*). Chum salmon are primarily captured during the B season and Chinook salmon during both the A and B seasons.

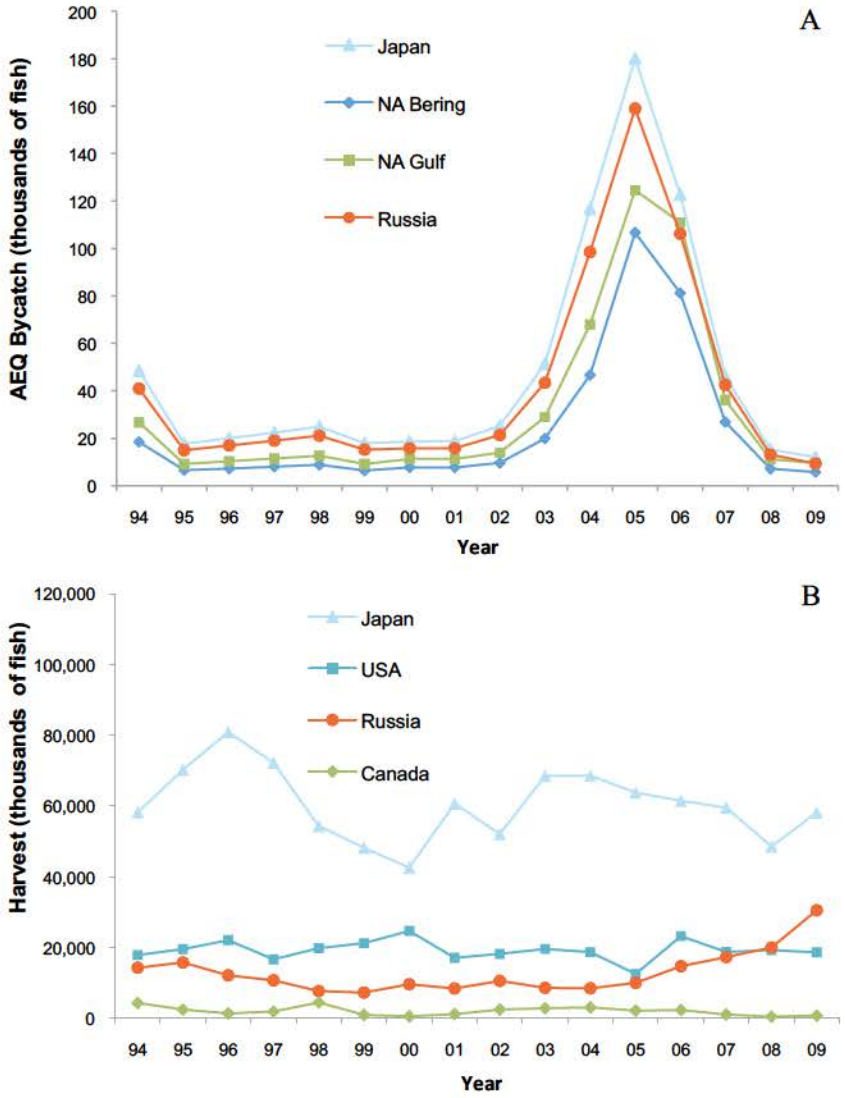

Figure 1. (A) Chum salmon adult equivalent mortality (AEQ) by the Bering Sea pollock fishery (provided by the North Pacific Fishery Management Council). Chum salmon stocks were grouped by: North American stocks from the Bering Sea (NA Bering), North American stocks from the Gulf of Alaska (NA Gulf), Japanese, and Russian stocks of chum salmon. (B) Chum salmon harvests by country (provided by the North Pacific Anadromous Fish Commission).

Pacific salmon represent an important resource to the people of Alaska and the North Pacific Rim. Within Alaska, salmon support large-scale commercial fisheries as well as subsistence fisheries, many of which form the basis of cultural traditions. Salmon bycatch management and patterns in the Bering Sea walleye pollock fishery were summarized in Stram and Ianelli (2009), and the possible effects of salmon bycatch on western Alaska communities were described in Gisclair (2009). The information presented in these papers suggests that 1) Chinook and chum salmon bycatch may impact run strength to western Alaska rivers; 2) numbers and spatial and temporal patterns of salmon as bycatch to the fishery vary substantially among years; 3) western Alaska stocks are apparently more prominent in the Chinook salmon bycatch than in chum salmon bycatch; and 4) bycatch of Chinook and chum salmon increased during 2004-06, despite efforts to reduce salmon bycatch through fixed time and area closures.

In this article we attempt to address two possible explanations for the 2004-06 increase in chum salmon bycatch (Fig. 1A). First we briefly examine whether or not an increase in overall abundance of North Pacific chum salmon could explain the rapid increase in bycatch. Next, we utilize data from BASIS research surveys to determine if a shift in their distribution occurred in the Bering Sea which may have made chum salmon more vulnerable to the commercial fishing fleet.

Chum Salmon Marine Ecology

Pacific salmon are distributed in the North Pacific Ocean and Bering Sea in summer but are primarily found in the North Pacific Ocean during winter (Fig. 2). The general migration pattern for North Pacific chum salmon stocks is to migrate to the Bering Sea from the North Pacific Ocean during spring and remain in the Bering Sea until late fall before heading south for winter. The Pacific Rim countries that have abundant chum salmon stocks include Japan, Russia, the United States, and Canada (Fig. 3). These chum salmon stocks are a mixture of hatchery and wild salmon. In fact, hatchery production of chum salmon exceeds 3.0 billion each year, followed by production of pink, sockeye, Chinook, and coho salmon, respectively (Fig. 4). Japan produces almost entirely hatchery-reared chum salmon (nearly 2.0 billion each year), whereas the other countries have a mixture of hatchery-reared and wild stocks.

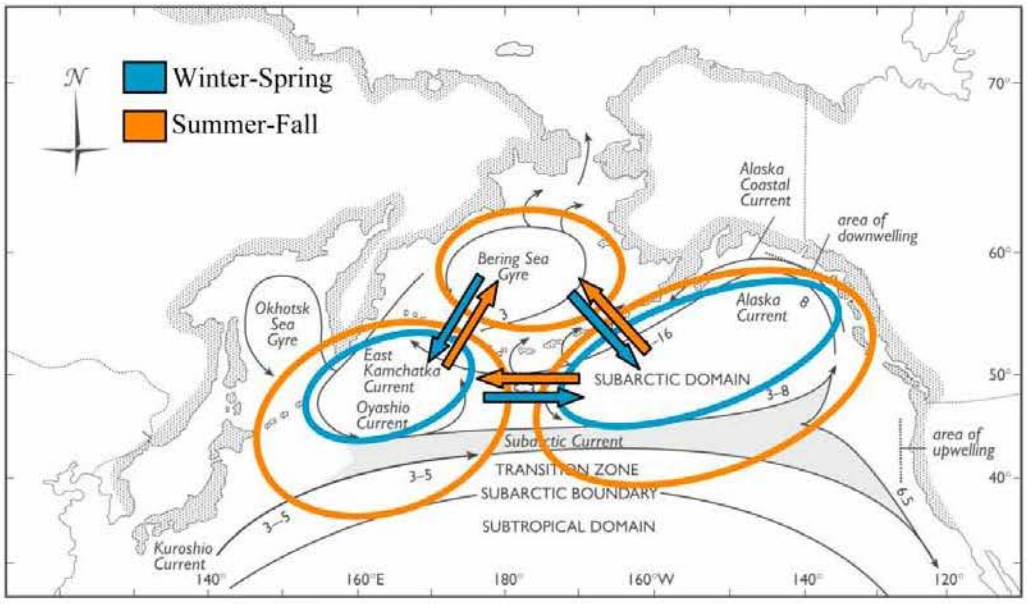

Figure 2. A general concept model of seasonal distribution and migration of Pacific salmon in the open ocean. Map is from Myers et al. (2007).

Abundance

During the summer months, immature (ocean age-1 and higher) chum salmon from all the Pacific Rim countries enter the Bering Sea to feed and grow. Some of these chum salmon are captured as bycatch during the Bering Sea walleye pollock fishery. Recent analysis of chum salmon bycatch suggests that the numbers of chum salmon caught during the walleye pollock fishery remained fairly constant from the mid-1990s to 2003 (Fig. 1A). Genetic stock composition analysis suggests that chum salmon from Japan consistently had the highest numbers of fish captured in the bycatch followed by Russian stocks, North American Gulf of Alaska stocks, and North American Bering Sea stocks. There was an increase in bycatch for all chum salmon stocks during 2004-06 followed by a decrease for all stocks during 2007-09. Harvest and production levels of chum salmon from the mid-1990s to 2009 also varied among the Pacific Rim countries (Fig. 1B). However, when comparing harvest and bycatch trends, it does not appear that the variability in abundance of chum salmon can account for the increase in bycatch in 2004-06.

Distribution

The Bering Sea has been the recent focus of marine research by the North Pacific Anadromous Fish Commission (NPAFC). Member nations of the NPAFC developed BASIS as an international cooperative research program designed to address concerns over the distribution, growth, and survival of salmon in the Bering Sea. BASIS surveys were initiated in 2002 and have occurred annually during summer and early fall months depending on the region of the Bering Sea surveyed (western, basin, eastern).

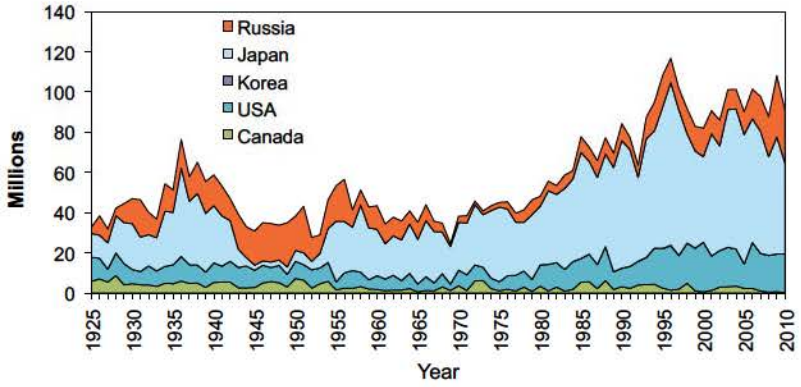

Figure 3. Chum salmon catch (millions) by country during 1925 to 2010 (data courtesy of the North Pacific Anadromous Fish Commission).

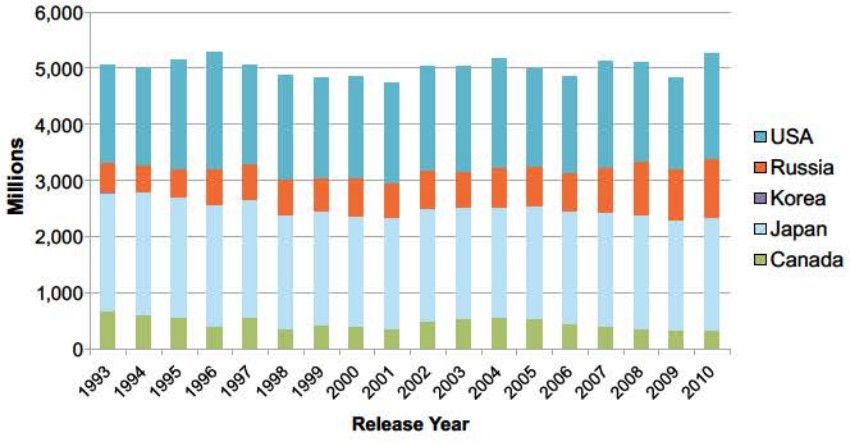

Figure 4. Hatchery production (millions) of salmon by species during 1993 to 2010 (data courtesy of the North Pacific Anadromous Fish Commission).

Chum salmon bycatch can occur throughout the fishing season, but nearly all chum salmon bycatch occurs during the summer and fall. Much of the chum salmon bycatch occurs along the outer eastern Bering Sea shelf region with hotspot locations found in the southeastern Bering Sea region (Fig. 5). However, these bycatch hotspots located on the outer shelf are in sharp contrast to the overall distribution of immature chum salmon in the Bering Sea. For instance, while BASIS surveys indicate that immature chum salmon do move onto the shelf in the northern and southern regions, the highest concentrations of immature chum salmon are found in the deeper, basin region during summer months (Fig. 6).

BASIS surveys conducted by the United States along the eastern Bering Sea shelf typically have occurred between mid-August to early October. Because these surveys have occurred later in the summer, limited connections can be made with chum salmon bycatch that occurs in the early summer months (June and July). However, peak bycatch has generally occurred during August and September and is consistent with the timing of the surveys. For instance, the relationship between chum salmon distribution and bycatch hotspots can be seen in the 2006 BASIS survey (Figs. 7A and B). Similar to the generalized offshore distribution of immature chum salmon, on-shelf movement of chum salmon is seen in both the northern and southern Bering Sea regions. Bycatch hotspots south of the Pribilof Islands correspond to locations of elevated chum salmon abundance from the BASIS survey in what appears to be on-shelf movement of chum salmon.

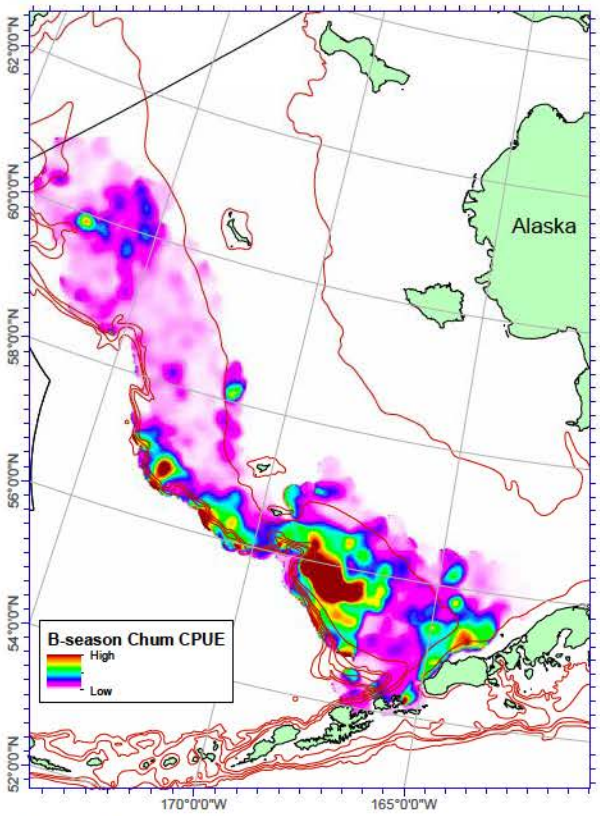

Figure 5. Mean (2003-06) catch per unit effort (number of fish per hour) of chum salmon caught as bycatch in the walleye pollock fishery. Darker color represents areas with higher CPUE.

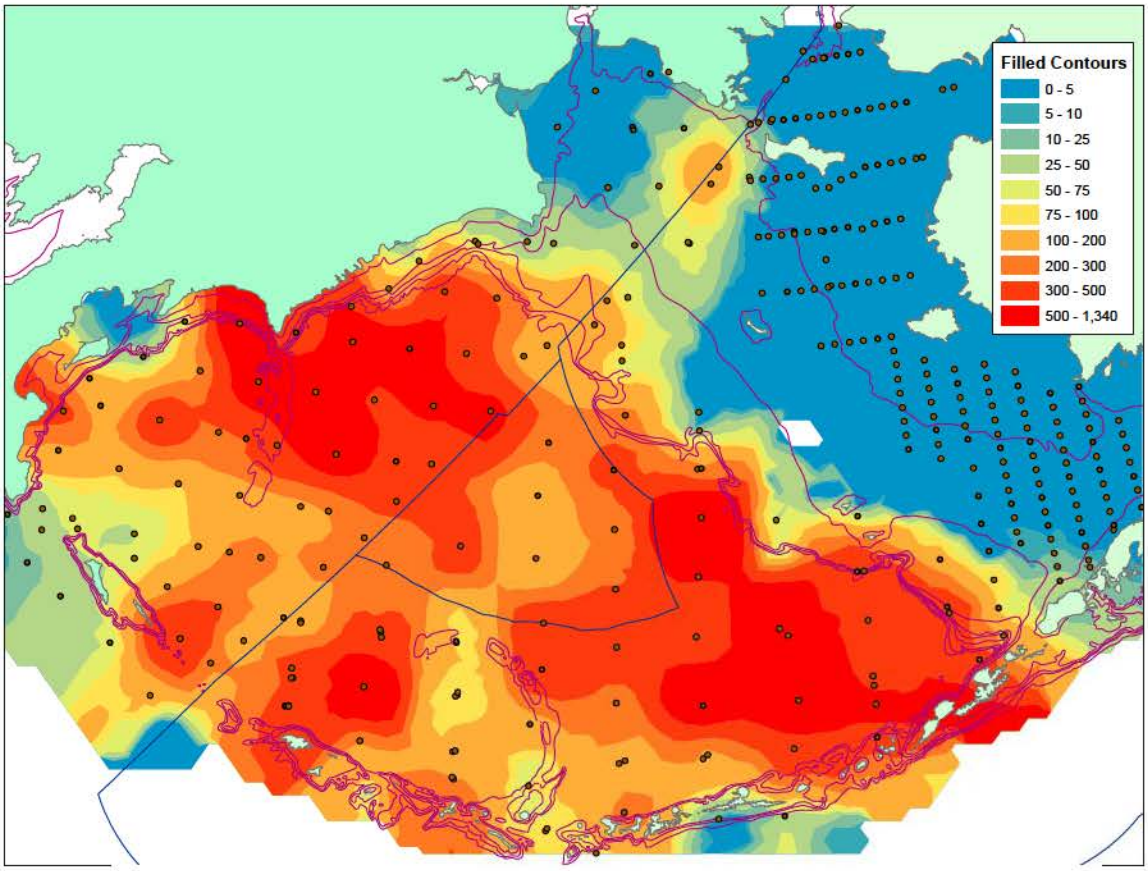

Figure 6. Distribution of immature/maturing chum salmon during mid-August to October 2002. Data are from BASIS research surveys conducted in western, central, and eastern Bering Sea during summer and early fall 2002. Black dots refer to stations sampled for salmon. Shading represents areas of no (white) to high (dark) immature chum salmon catch.

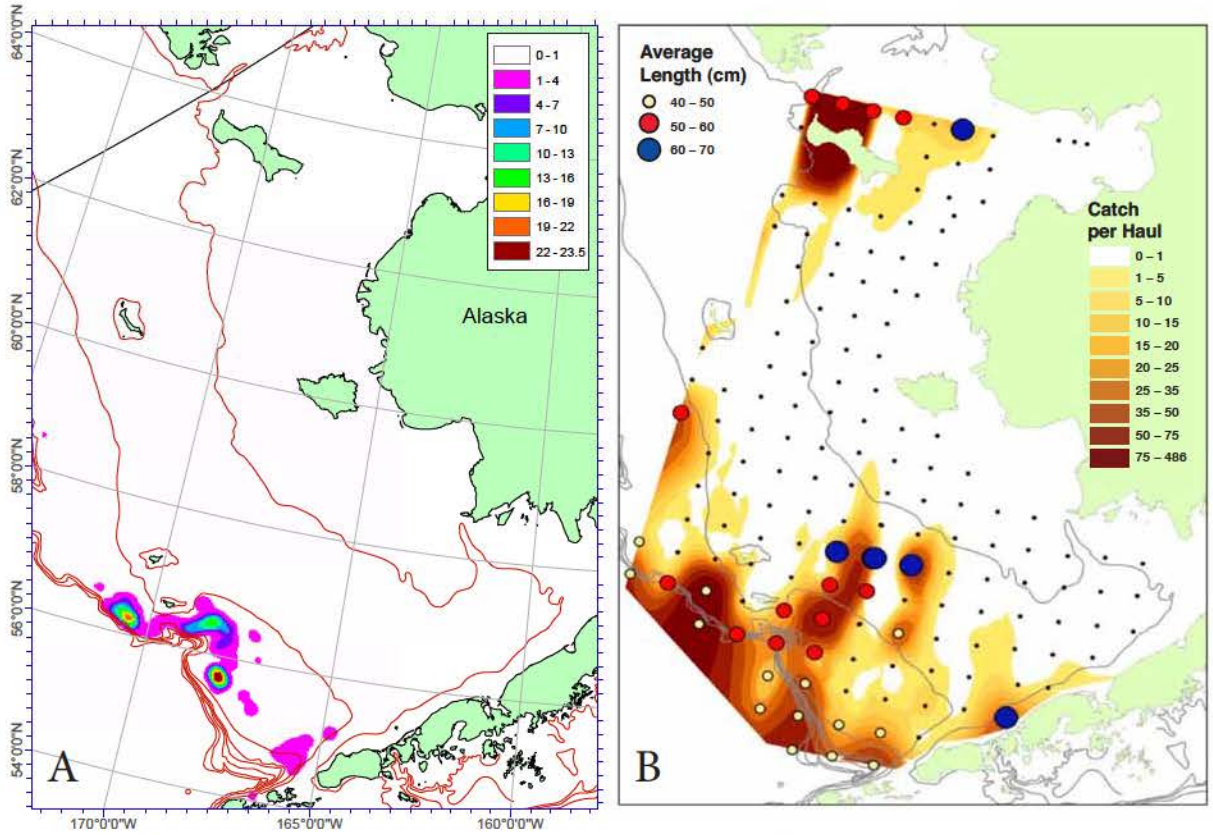

Figure 7. (A) Bycatch hotspots in Bering Sea walleye pollock trawl fisheries during August to September 2006. (B) Chum salmon distribution during the 2006 mid-August to October BASIS survey. Colored symbols in the BASIS survey distribution identify the average size of chum salmon at each location; only locations with catches greater than 20 are shown (blue: > 60 cm, red: 50-60 cm, white: 40-50 cm).

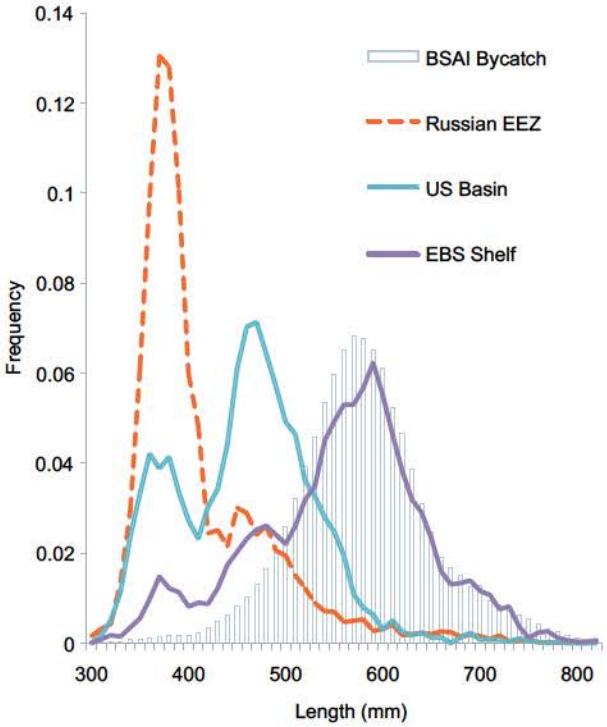

Figure 8. Length frequency distribution of chum salmon in the Bering Sea. Regions include the Russian exclusive economic zone (EEZ) (Russian EEZ), U.S. and international waters offshore of the eastern Bering Sea (EBS) shelf (U.S. Basin), U.S. BASIS on the eastern Bering Sea shelf (EBS Shelf), and the EBS shelf where chum salmon were captured as bycatch in U.S. pelagic trawl fisheries (BSAI Bycatch).

Our survey data suggest that movement of chum salmon from the Bering Sea basin onto the shelf and into the fishery is ultimately the key feature that establishes bycatch potential, whereas the ability of fishermen to avoid catching chum salmon determines bycatch. The average length of immature chum salmon from BASIS research surveys illustrates that chum salmon migrating from the basin to the shelf are composed of the largest or oldest fish (Fig. 7B). Similarly, the larger chum salmon are captured as bycatch in the pollock fishery, whereas the smallest (and youngest) fish are distributed in the western Bering Sea and across the Bering Sea basin (Fig. 8). Moreover, the large biomass of chum salmon just offshore of the fishery emphasizes that species-level movement patterns such as changes in migratory trajectories or foraging behavior, particularly by larger chum salmon, could significantly alter the overlap of chum salmon with the fishery.

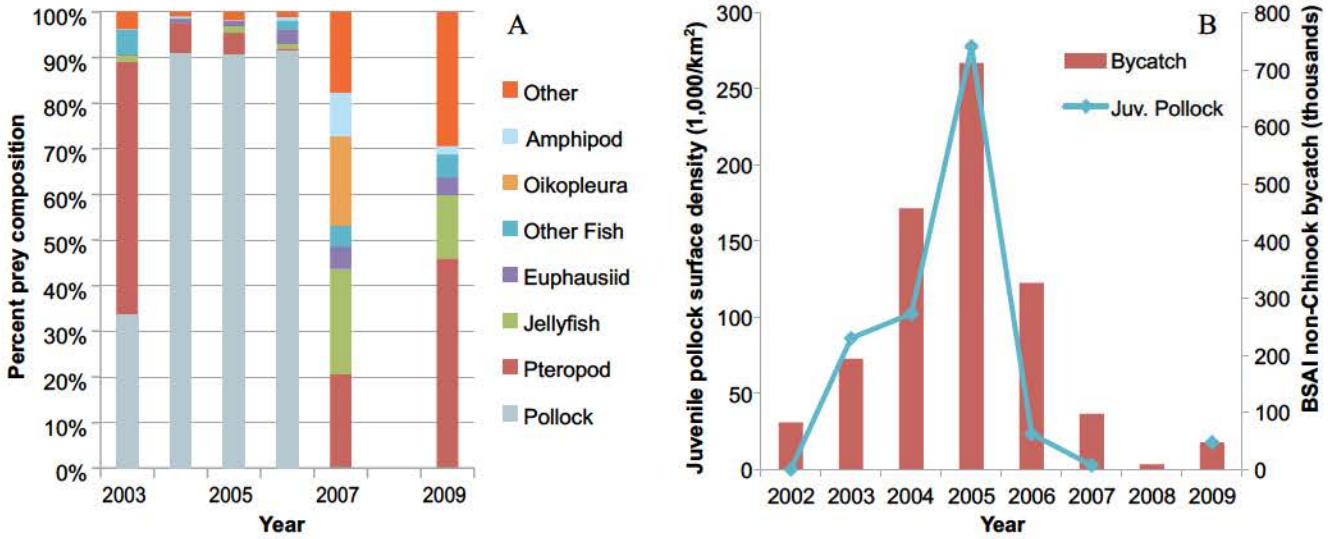

Figure 9. (A) Diet composition of immature/maturing chum salmon in the outer domain of the southern Bering Sea shelf. (B) Relationship between surface trawl catches of juvenile (age-0) pollock in the outer domain and bycatch of chum salmon in Bering Sea groundfish fisheries.

Chum salmon foraging behavior

Understanding factors affecting movement of immature chum salmon from the basin and onto the outer Bering Sea shelf is a key component to determining bycatch potential. Salmon diet and prey field information was collected each year (from 2002 to 2009) during the BASIS surveys to provide insight into the foraging behavior of chum salmon. Our data indicate that during 2004-06, over 90% of the prey (by weight) for immature chum salmon was age-0 walleye pollock (Fig. 9A). Immature chum salmon diets shifted to a mix of prey species including pteropods, oikopleura, and other items during 2007-09. Another key feature of the BASIS survey is our ability to sample pelagic fish prey such as age-0 walleye pollock and Pacific cod. The trawl used during the survey captures these fish in the surface waters (surface to 30-m depth) at depths where immature chum salmon are distributed. Based on our trawl catches, relative abundance of the age-0 walleye pollock found above 30-m depth were highest in the survey region during 2004-06.

Evening on the Bering Sea during a BASIS research cruise. Photo by Lisa Eisner.

Because these surface distributions of age-0 pollock are found primarily on the eastern Bering Sea shelf, they could be one possible factor affecting movement of immature chum salmon from the basin to the shelf region. To test this hypothesis, we related the surface densities of age-0 walleye pollock from BASIS surveys to the total bycatch of chum salmon (Fig. 9B). We note that there is a strong relationship between age-0 pollock surface densities and the total chum salmon bycatch, suggesting that peak chum salmon bycatch during 2004-06 occurred during a period of increased densities of age-0 walleye pollock in surface waters of the eastern Bering Sea. Therefore, increased chum salmon prey density in surface waters (2004-06) on the outer shelf may have been one factor driving the movement of immature chum salmon from the basin and onto the outer shelf, thereby contributing to increased bycatch potential during the peak bycatch years (2004-06).

AFSC fishery biologist Alex Andrews with maturing chum salmon captured during a BASIS research cruise in the Bering Sea.
Photo by Lisa Eisner.

Conclusion

Our survey data suggest that increased bycatch of chum salmon during 2004-06 may have been an artifact of increased prey density along the outer shelf of the eastern Bering Sea. We conclude that these 'foraging hotspots' for chum salmon could contribute to an increased movement of larger (older age) fish from the basin onto the shelf, or they could simply retain chum salmon within the fishery, making them vulnerable to bycatch for a longer period of time.

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