Distributions of Oceanographic Variables, Juvenile Sockeye Salmon and Age-0 Walleye Pollock in the Southeastern Bering Sea during Fall 2000–2003

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We conducted surveys in Bristol Bay on the southeastern Bering Sea shelf during late August to mid-September 2000–2003, as part of the Bering-Aleutian Salmon International Survey (BASIS). Our main objective was to compare biological and physical oceanographic characteristics to the distributions of juvenile sockeye salmon (*Oncorhynchus nerka*) and age-0 walleye pollock (*Theragra chalcogramma*) during fall in the southeastern Bering Sea. We characterize the horizontal and vertical structure of oceanographic variables for 2000 to 2003, and then describe how spatial and temporal variations in oceanographic characteristics relate to juvenile sockeye salmon and age-0 walleye pollock distributions. This characterization of marine habitat provides important information for understanding relationships among climate, oceanography, lower trophic levels, and forage fish (including juvenile salmon and pollock).

Stations were generally spaced 15–30 km apart in Bristol Bay, although spatial coverage varied by year. Surface fish trawls were conducted with a rope trawl (Cantrawl models 400 and 300, ~15 m deep by 55 m wide) towed for 30 minutes at 3.5–5 knots. Abundance, weight, and length were recorded for salmon and associated species. Vertical profiles of temperature, salinity, and chlorophyll a (chl a) fluorescence were conducted to within 10 m of the bottom using a Sea-Bird 19 or Sea-Bird 25 CTD (Conductivity-Temperature-Depth) profiler. During 2003, we also collected discrete samples at select depths for chl a, nutrients, and phytoplankton species. Chl a samples were filtered onto GF/F filters, stored frozen, extracted in 90% acetone, and analyzed with a Turner Model TD-700 fluorometer (Parsons et al. 1984). Nutrients were stored frozen and analyzed with a Technicon Auto Analyzer following standard colorimetry protocols (UNESCO 1994). Phytoplankton species were preserved in buffered formalin and taxa greater than 5–10 µm in diameter were quantified using the inverted microscope technique (Lund et al. 1958).

Surface (5 m) temperature and salinity values indicated that 2002 and 2003 had higher sea surface temperatures than 2000 and 2001 (Fig. 1). Surface salinities were lower in 2003 than in 2000–2002 (Fig. 1). In 2003, surface chl a values were high in southern Bristol Bay and along the longitude 166° W transect, although distributions were patchy (Fig. 2). Dissolved Inorganic Nitrogen (DIN) concentrations were high (> 5 µM) below the pycnocline throughout Bristol Bay and near the surface in southern Bristol Bay (Fig. 2). Upwelling of water through Unimak Pass (Stabeno et al. 2002) likely introduced this nutrient-rich water into southern Bristol Bay and subsequently fueled production in this area.

**Fig. 1.** Surface (5 m) temperature (°C) and salinity from CTD data for late August to mid-September for 2000–2003 in the southeastern Bering Sea.
An evaluation of vertical sections of CTD data along the longitude 164°W transect indicated that temperatures below the pycnocline and near the surface were cooler in 2000 and 2001 than in 2002 and 2003, in agreement with data from the M2 mooring at 56.8°N, 164°W (Overland and Stabeno 2004). During all years, we observed relatively high surface chl a fluorescence near the 50-m isobath, the approximate vicinity of the Inner Front separating the well-mixed coastal waters from the stratified Middle Domain (Schumacher and Stabeno 1998). The Inner Front region can be an area of prolonged primary production (Kachel et al. 2002), which in turn stimulates production at higher trophic levels. In 2003, relatively high subsurface chl a fluorescence values were observed at the base of the pycnocline in the Middle Domain, whereas high surface values were seen near the southern end of the transect in the area with high surface DIN (Fig. 2). Examination of the phytoplankton taxa indicated that the subsurface blooms were predominantly dinoflagellates, with diatoms seen closer to the northern coast and in the surface waters at the southern end of the longitude 164°W transect.

Juvenile sockeye salmon were more abundant and distributed further south in 2002 and 2003 compared to 2000 and 2001 (Fig. 3). The higher abundances may be associated with the higher surface temperatures during the latter two years (Figs. 1, 3). Age-0 walleye pollock, a primary prey of juvenile sockeye salmon, were also more abundant during our surveys in 2002 and 2003 than in 2000 and 2001 (Fig. 3). Subsets of the juvenile sockeye salmon and age-0 walleye pollock distributions along the longitude 164°W transect were located in the cooler water advected into Bristol Bay from Unimak Pass (Figs. 1, 3). Because this water contained different phytoplankton species, it is possible that the forage fish in this area were influenced by different food web dynamics than assemblages found farther north in Bristol Bay.

**Fig. 2.** Surface (5 m) chlorophyll a (µg L⁻¹) and dissolved inorganic nitrogen (DIN, µM-N) determined from discrete samples analyses for 2003. Stations indicated by open circles. Solid black line is the approximate location of the inshore edge of the Inner Front.

**Fig. 3.** Juvenile sockeye salmon and age-0 walleye pollock distributions (catch for 30-min trawl) for 2000–2003.
Extensive blooms of coccolithophores (calcareous phytoplankton that scatter light and give the water a chalky, aquamarine appearance) were observed in the Bering Sea during 1997–2001 (Iida et al. 2002). A comparison of the juvenile sockeye salmon and coccolithophore distributions for 2000 indicated that the juvenile sockeye salmon were generally distributed outside of the bloom area, farther south than typically observed (Fig. 4). Coccolithophore blooms could negatively influence juvenile salmon by obscuring visibility for effective capture of prey or may promote a less productive food web since coccolithophores can be a less desirable prey for lower trophic level organisms such as microzooplankton (Olson and Strom, 2002). As compared to earlier years (Iida et al. 2002), we observed a much less extensive coccolithophore bloom during our survey in 2003 and did not observe a bloom in 2002.

In conclusion, the higher temperatures and lack of extensive coccolithophores blooms may have contributed to higher juvenile sockeye salmon survival during 2002 and 2003. Subsets of age-0 walleye pollock and juvenile sockeye salmon were seen in the cooler, nutrient-rich water advected through Unimak Pass. Different phytoplankton taxa and vertical distributions were seen in this nutrient-rich water than in the two layer system father north, suggesting food web components and interactions varied between the Middle Domain and the southern Bristol Bay waters.

REFERENCES


