Factors Affecting Distribution, Migration, and Growth of Juvenile Sockeye Salmon in the Eastern Bering Sea (July and September 1999)

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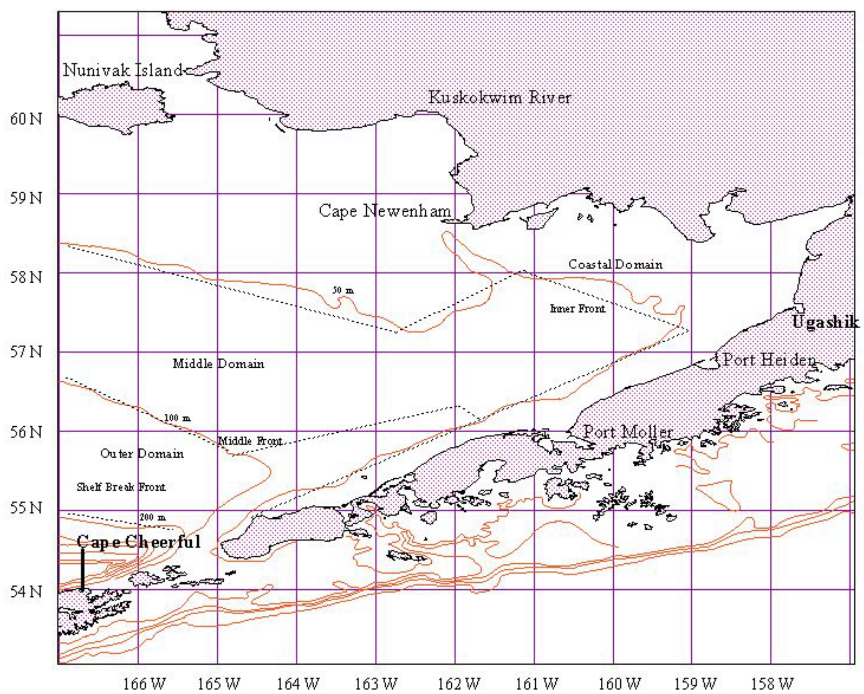
Keywords: Sockeye salmon, juvenile, Bristol Bay, Bering Sea

Eastern Bering Sea research cruises were conducted by the Auke Bay Laboratory, Ocean Carrying Capacity (OCC) program during July and September 1999 to study the early marine distribution, migration, and growth of juvenile Bristol Bay sockeye salmon (*Oncorhynchus nerka*). The survey area was bounded to the west by Cape Cheerful and to the east by the Ugashik River, crossing the coastal, middle, and outer domains of the eastern Bering Sea (Fig. 1). The 1999 surveys were the first in a series of annual assessments to document variations in the biological characteristics (growth, migration, and distribution) of juvenile sockeye salmon leaving Bristol Bay (Farley et al. 1999). The primary goal of the annual assessments is to establish and verify the linkages between adult sockeye salmon survival and annual variations in biological characteristics of juvenile sockeye salmon.

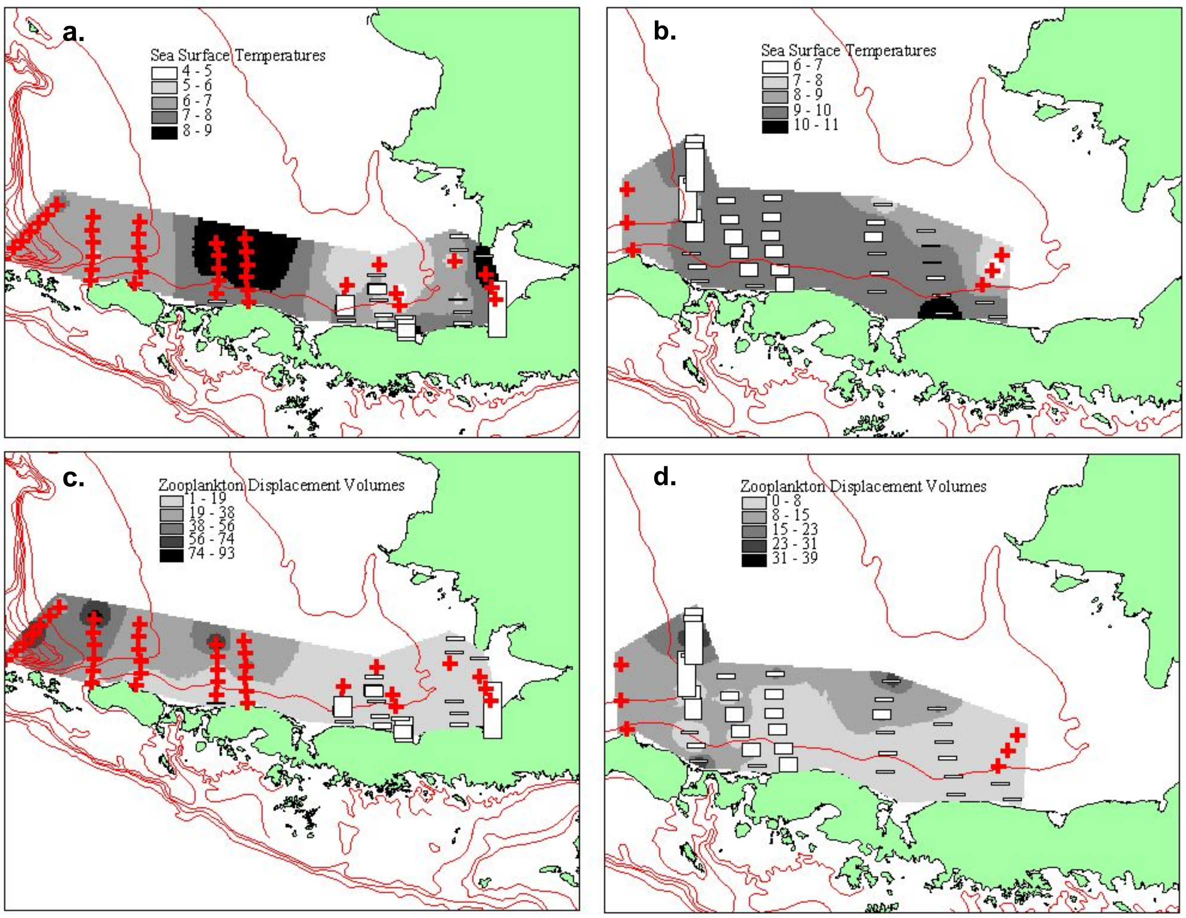
Fig. 1. Area surveyed by the F/V *Great Pacific* (coastal waters of the eastern Bering Sea from Cape Cheerful to Ugashik) during July and September 1999.



Past studies of Bristol Bay sockeye salmon have given us a good description of the habitat and migration characteristics of juvenile sockeye salmon as they leave Bristol Bay, moving along the north shore of the Alaska Peninsula (Straty 1974; Straty and Jaenicke 1980; Straty 1981). These studies have also shown how juvenile salmon respond to environmental conditions along their migration path, suggesting the following conceptual model of the affects of marine environment on distribution, migration, and growth of juvenile Bristol Bay sockeye salmon in the eastern Bering Sea: (1) the distribution of juvenile sockeye salmon in the coastal waters of Bristol Bay is influenced by environmental conditions such as temperature and salinity; (2) migration rates vary as a function of temperature, food density, juvenile salmon body size, and stock origin; and (3) growth rates are related to migration rates, coastal distribution patterns, and food production in Bristol Bay.

The 1999 surveys were designed to test for seasonal (summer and fall) differences in distribution, migration, and growth of juvenile sockeye salmon along the coastal waters of the eastern Bering Sea and also to substantiate the conceptual model. During July, most of the juvenile sockeye salmon were encountered northeastward of Port Moller, and were distributed from nearshore to 74 km offshore (Fig. 2a). The extent of offshore distribution of juvenile sockeye salmon during July may have been related to sea surface temperatures. Sea surface temperatures during this period indicated that a cold pool of surface water (< 6ºC) was located offshore between Port Moller and Port Heiden (Fig. 2a). Juvenile sockeye salmon were encountered shoreward of the cold pool, apparently preferring the warmer surface waters along the coast. Most of the juvenile sockeye salmon encountered during September were southwestward of Port Moller, and were distributed from nearshore to 150 km offshore (Fig. 2b). The expanded offshore distribution of juvenile sockeye salmon encountered during September may have been the result of increased sea surface temperatures (> 8.5ºC) within this area.

Fig. 2. Contours of sea surface temperatures (°C) (a and b) and zooplankton displacement volumes (ml•m^{-2}) (c; 333 µm mesh and d; 505 µm mesh) and associated juvenile sockeye salmon catch in the eastern Bering Sea during July (a and c) and September (b and d). Bars indicate areas where juvenile sockeye salmon were caught, larger bars indicate larger catch. Plus signs indicate areas sampled where no juvenile sockeye salmon were caught.



The 1999 OCC summer and fall surveys were unique in that they occurred after a cold spring in the eastern Bering Sea, which was characterized by a delay in the breakup of lake-ice in sockeye salmon nursery lakes and anomalously cold sea temperatures (Farley et al. 1999). The cold spring may have delayed the seaward migration of juvenile sockeye salmon. For example, during July we caught only one juvenile sockeye salmon west of Port Moller; whereas, past studies of juvenile salmon migration in the eastern Bering Sea that occurred after relatively warm springs, indicated that large catches of juvenile sockeye salmon could occur west of Port Moller during this time period (Straty and Jaenicke 1980; Hartt and Dell 1986; Isakson et al. 1986).

Our 1999 survey results suggest that the anamolously cold spring and surface water temperatures possibly delayed offshore migration of juvenile sockeye salmon into areas of greater forage densities, affecting their early marine growth. During July and September 1999, zooplankton densities (ml·m^{-2}) were greatest within the middle domain and within the coastal domain west of Port Moller (Fig. 2c,d). Differences in seasonal distribution of juvenile sockeye salmon (distributed within low zooplankton densities during July and high zooplankton densities during September) may explain the significantly higher growth and condition factor found for juvenile sockeye salmon captured during September than those captured during July (Table 1). Similar observations of early marine distribution, migration, and growth of juvenile sockeye salmon encountered within the coastal waters of the eastern Bering Sea during the summer of 1971 (which followed a anamolously cold spring) by Straty (1974) were followed

Table 1. Number of samples (*n*) and mean and standard deviation (SD) of length (mm), weight (g), and condition factor (k) by freshwater age of juvenile sockeye salmon collected during July and September 1999. Numbers that are bold indicate significant differences ($p < 0.01$).

	Length			Weight		Condition	
	n	mm	SD	g	SD	k	SD
Age 1.							
July	646	92.8	11.0	7.0	2.93	0.990	0.06
September	248	**145.7**	16.4	**32.4**	11.9	**1.008**	0.03
Age 2.							
July	282	124.9	15.3	19.0	7.1	0.998	0.09
September	108	**168.9**	22.3	**51.8**	20.8	**1.020**	0.06

by dramatically reduced adult sockeye salmon returns to Bristol Bay two (1973) and three (1974) years later. If this qualitative comparison holds true, then we may expect lower than average returns of 2-ocean sockeye salmon to Bristol Bay during summer 2001.

The authors thank the Alaska Boat Company, particularly Captain Charles J. (Jack) Bronson and Captain Mathew Zimny and the crew of the F/V *Great Pacific* for their fine efforts on behalf of our research goals. We also thank staff from Fisheries Oceanographic Coordinated Investigations (FOCI) especially Christine Baier for her support in zooplankton collections during the July survey. Funding for processing the July zooplankton collections was provided by FOCI. The National Marine Fisheries Service, Alaska Regional Office, provided funding support for the September 1999 cruise.

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