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Eastern Bering Sea (Bristol Bay) Coastal Research on Bristol Bay Juvenile Salmon, July and September 1999

by

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Submitted to the
NORTH PACIFIC ANADROMOUS FISH COMMISION
by the

UNITED STATES OF AMERICA

October 1999

THIS PAPER MAY BE CITED IN THE FOLLOWING MANNER:

Farley, E.V., Jr., J.M. Murphy, R.E. Haight, G.M. Guthrie, C.T. Baier, M.D. Adkison, V.I. Radchenko, and F.R. Satterfield 1999. Eastern Bering Sea (Bristol Bay) Coastal Research on Bristol Bay Juvenile Salmon, July and September 1999. (NPAFC Doc.) Auke Bay Laboratory, Alaska Fisheries Science Center, NMFS, NOAA, 11305 Glacier Highway, Juneau, AK 99801-8626. 22 p.

Abstract

Eastern Bering Sea research cruises were conducted by the Auke Bay Laboratory Ocean Carrying Capacity program during July and September 1999 to study the possible affects of marine environment on distribution, migration, and growth of juvenile Bristol Bay sockeye salmon. The 1999 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. During July, most of the juvenile sockeye salmon were encountered northeastward of Port Moller and were distributed from nearshore to 74 km offshore. During September, most of the juvenile sockeye salmon were encountered southwestward of Port Moller to 111 km east of Unimak Pass and were distributed from nearshore environment to 111 km offshore and further (150 km offshore) along the 100 m shelf break. The expanded distribution of juvenile sockeye salmon encountered during September 1999 may have been the result of increased sea surface temperatures. During July 1999, juvenile sockeye salmon were only encountered when sea surface temperatures were 6 degrees C or more; sea surface temperatures in offshore waters during July were 4 to 5 degrees C. During September 1999, sea surface temperatures had warmed considerably; nearshore sea surface temperatures were 10 to 10.5 degrees C, while offshore surface water temperatures were 8.5 to 9.5 degrees C.

Increased sea surface temperatures may also have lead to rapid increase in growth. During July 1999, juvenile sockeye salmon were generally small in size, ranging from 80 to 105 mm near the coast to 105 to 115 mm off Port Moller. During September 1999, juvenile sockeye salmon lengths near the coast ranged from 105 to 140 mm, while lengths of juvenile sockeye salmon encountered at offshore locations ranged from 190 to 240 mm. Analyses of plankton, stomach contents, fresh water age, and scale growth data collected during both surveys will be done to shed additional light on the growth and migration characteristics of juvenile sockeye salmon emigrating from Bristol Bay.

Introduction

During 1997 and 1998, lower than expected returns of sockeye salmon to Bristol Bay prompted the State of Alaska and the U. S. Department of Commerce to declare the Bristol Bay region an economic disaster area. The cause of the disastrous returns of sockeye salmon to Bristol Bay is not fully understood, but may be related to changes in the marine environment. Fishery scientists generally agree that conditions in the ocean, particularly in the first few months after leaving freshwater, strongly influence interannual variability in salmon survival and growth (Parker 1962; Pearcy 1992). The assumption is that growth rates of juvenile salmon in the estuarine and nearshore marine environments are directly linked to their survival. Thus, years with favorable environmental conditions and increased growth rates of juvenile salmon may result in improving their early marine survival, ultimately affecting total returns of salmon in the following years.

Past studies suggest the following conceptual model on the possible affects of marine environment on distribution, migration, and growth of juvenile Bristol Bay sockeye salmon in the eastern Bering Sea (Straty 1974; Straty and Jaenicke 1980; Straty 1981):

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.

During July and September 1999, the Auke Bay Laboratory conducted surveys of juvenile salmon distribution, migration, and growth along the coastal waters of the eastern Bering Sea. The 1999 surveys were the first in a series of annual assessments to substantiate the conceptual model and document variations in the biological characteristics (growth, migration, and distribution) of juvenile sockeye salmon leaving Bristol Bay. 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.

Methods

Coastal surveys of the eastern Bering Sea were conducted during July 12 to 26 and September 2 to 12, 1999. The survey area was bounded to the west by Cape Cheerful (off of Unalaska Island) and to the east by the Egegik River in Bristol Bay (Figure 1). The cruise itineraries and participating scientists are listed in Tables 1 and 2, respectively. Transects sampled during the surveys were perpendicular to the coast and generally 55 to 110 km apart. Sampling at each transect began near the coast then continued offshore with stations every 18.5 km to at least 110 km or further if large catches of juvenile sockeye salmon occurred at offshore stations.

Both surveys were conducted aboard the contracted fishing vessel (F/V) *Great Pacific*. The vessel is a 38-m stern trawler with a main engine of 1450 horsepower and a cruising speed of 10 kts. Fish samples were collected using a midwater rope trawl, which is 198 m long, has hexagonal mesh in wings and body, and has a 1.2-cm mesh liner in the codend. The rope trawl was towed at 4 to 5 kts, at or near surface, and had a typical spread of 52 m horizontally and 18 m vertically. All tows lasted 30 minutes and covered 2.8 to 4.6 km. Most sampling was done during daylight hours; during the July 1999 survey, one nearshore station at Strogonof Point was repeated 6 times (once every 4 hours for a 24 hour period) to document variability in catch between trawl hauls and possible differences in catch between day and night.

Salmon and other fishes were sorted by species and counted. Standard biological measurements including fork length, body weight, and sex as well as scale samples from the preferred area (to document age and growth) were taken from subsamples of all salmon species. Juvenile chum and sockeye salmon were frozen whole at –60˚C for genetic analyses. During the July 1999 cruise, we caught several hundred immature chum salmon west of Port Moller. One of the objectives of the Ocean Carrying Capacity program is to document distribution and migration of hatchery salmon whose otoliths were thermally marked during incubation. Therefore, we saved otolith and scale samples from immature chum salmon to identify hatchery origin and to document growth. All other fish species were counted and stomach contents as well as biological measurements including length and body weight were taken from subsamples of each species and stomach contents frozen for later laboratory analyses.

Oceanographic data were also collected at each trawl station immediately prior to each trawl haul. Depth profiles of salinity and temperature from surface to near bottom depths at each trawl station were collected using a Sea-Bird SBE 19 Seacat profiler. Plankton samples were collected at each trawl station using 60- and 20-cm diameter bongo samplers fitted with 333- and 153 μm mesh nets, respectively. The smaller bongo was attached to the towing wire 1 m above the large frame. Double oblique tows were made from near surface to approximately 10 m from the bottom; estimated depth of bongo tow was calculated by wire angle and length of wire out. Volume of water filtered by each net was estimated by flow meters. Plankton samples were preserved in 5% buffered Formalin. and will be processed in the coming year by the Polish Plankton Sorting & Identification Center according to protocols developed by the Recruitment Processes Team (RACE Division) of the AFSC.

Results

July

During the July 12 – 26 survey, 10 transects were sampled and 64 trawl stations were completed beginning at Cape Cheerful off of Unalaska Island and ending near Cape Greig, east of Ugashik River (Figure 2). A total of 3,145 salmon representing 5 species (*Oncorhynchus* spp.) were captured (Table 3). The vast majority of salmon caught were juvenile salmon including sockeye (*O. nerka*; 72%), coho (*O. kisutch*; 9%) and chinook salmon (*O. tschawytcsha*; <1%). No juvenile chum (*O. keta*) or pink (*O. gorbuscha*) salmon were captured during the survey. Immature and maturing salmon occurred less frequently; immature chum, sockeye, and chinook salmon comprised 10%, <1%, and <1% of the catch, respectively. Maturing sockeye and chinook salmon also comprised less than 1% of the catch each, while maturing pink and chum salmon comprised 2% and 4%, respectively. Other species captured during the survey are listed in Table 4.

Juvenile sockeye salmon were mainly distributed north and east of Port Moller with the largest catch per unit effort (CPUE) east of Ugashik River near Cape Greig and the smallest CPUE at Cinder River (Figures 2 and 3). The largest concentrations of juvenile sockeye salmon were found nearshore (less than 18.5 km) for transects east of Port Heiden, whereas, juvenile sockeye salmon were distributed nearshore to as far as 74 km offshore for transects west of Port Heiden. Only one juvenile sockeye salmon was captured west of Port Moller at the nearshore station of Moffit Point. Average length of juvenile sockeye salmon varied with distance offshore. In general, juvenile sockeye salmon were smallest nearshore and increased in length with distance offshore (Table 5). The average length of all juvenile sockeye salmon subsampled during the survey was 106.1 mm (n=229; sd=22.6).

Sea surface temperatures varied with distance from shore and area. From Cape Cheerful to Cape Lieskof (west of Port Moller), sea surface temperature increased with distance offshore; whereas from Cape Seniavin to Cinder River (east of Port Moller) sea surface temperatures generally decreased with distance from shore (Table 6). Plankton samples collected during the survey will be analyzed in the upcoming year and the results will be used to document juvenile salmon distribution with respect to plankton abundance.

Repeat sampling at the Strogonof Point nearshore station indicated high variability between trawl hauls depending on time of day. Catch of juvenile sockeye salmon ranged from 3 to 25 during the first four trawl hauls which included one night time haul and 3 day time hauls (Figure 4). Catch of juvenile sockeye salmon increased dramatically for the last two trawl hauls, which included one day time haul (125 juvenile sockeye salmon) and on night time haul (159 juvenile sockeye salmon; Figure 4). The high variability in juvenile sockeye salmon catch may have been due to influx of salmon into the sampling area either by: 1) encountering new arrivals of salmon along during their seaward migration; or 2) the dramatic increase in offshore (east) winds; wind speed for the first 4 trawl hauls ranged from 5 to 15 knots, while wind speed for the last two trawl hauls ranged from 30 to 40 knots. The increased wind speed may have pushed juvenile sockeye salmon, located very nearshore and outside the trawl area, to more offshore locations.

September

During the September 2 – 12 survey, 7 transects were sampled and 42 trawl stations were completed beginning 55 km east of Cape Seniavin and ending near Cape Mordvinof (Figure 5). A total of 4,894 salmon representing 5 species were captured (Table 3). The largest component of the catch was juvenile salmon including sockeye (93%), chum (4%), coho (2%), pink (<1%), and chinook (<1%). Immature chum, sockeye, and chinook salmon comprised less than 1% of the catch each. Maturing pink, chum, sockeye, and coho salmon also comprised less than 1% of the catch each. Other species captured during the survey are listed in Table 4.

Juvenile sockeye salmon were distributed from Cape Krenitzin to 55.5 km east of Cape Seniavin (Figure 5). The largest concentrations of juvenile sockeye salmon were found west of Port Moller with the largest CPUE of juvenile sockeye salmon at Cape Krenitzin (Figure 6). No juvenile sockeye salmon were captured west of Cape Krenitzin. Juvenile sockeye salmon were distributed from nearshore areas to 110 km and beyond; the largest catch of juvenile sockeye salmon occurred at 130 km offshore of Cape Krenitzin. Average length of juvenile sockeye salmon increased with distance offshore and seaward along the migration path (Table 5). The average length of all juvenile sockeye salmon captured during the survey was 172.1 mm (n=732; sd=30.1).

Sea surface temperatures varied by distance offshore and location sampled. Sea surface temperatures were warmest at near-shore locations and coolest at offshore stations for transects sampled east of Port Moller. For transects west of Port Moller, sea surface temperature remained fairly uniform across the area surveyed. (Table 6).

Discussion

Juvenile sockeye salmon from all river systems entering Bristol Bay follow the same southeasterly seaward migration route along the coastal waters of the eastern Bering Sea (Straty 1974; Straty and Jaenicke 1980; and Straty 1981). The seasonal timing of this migration can be influenced by annual differences in environmental conditions, such as time of ice breakup on lakes and anomalously cold sea temperatures (Straty 1981). This was the first year the Ocean Carrying Capacity program conducted surveys in the eastern Bering Sea to examine effects of the environment on migration, distribution, and growth of Bristol Bay juvenile sockeye salmon. The 1999 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 (personal communication, Drew Crawford, Alaska Department of Fish and Game, Anchorage) and anomalously cold sea temperatures. 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).

The July and September 1999 surveys were designed to test for seasonal (summer and fall) differences in growth, distribution, and migration of juvenile salmon along the coastal waters of the eastern Bering Sea. During July, most of the juvenile sockeye salmon were encountered northeastward of Port Moller and were distributed from nearshore to 74 km offshore. During September, most of the juvenile sockeye salmon were encountered southwestward of Port Moller to 111 km east of Unimak Pass and were distributed from nearshore environment to 111 km offshore and further (150 km offshore) along the 100 m shelf break. This widespread occurrence of juvenile sockeye salmon in offshore waters differs from the historical model given by French et al. (1976), which indicates a coastal migration along the eastern Bering Sea (Figure 7). Future studies will be directed to study the extent of offshore migration during summer and fall.

The expanded distribution of juvenile sockeye salmon encountered during September may have been the result of increased sea surface temperatures. During July, juvenile sockeye salmon were only encountered when sea surface temperatures were 6 degrees C or more; sea surface temperatures in offshore waters where juvenile sockeye salmon were encountered during July were often below 6 degrees C. During September, sea surface temperatures had warmed considerably; nearshore sea surface temperatures were 10 to 10.5 degrees C, while offshore surface water temperatures were 8.5 to 9.5 degrees C. Increased sea surface temperatures during between July and September 1999 may have also lead to rapid increase in growth. During July, juvenile sockeye salmon were generally small in size, with an average length of 106.1 mm. During September, juvenile sockeye salmon had grown significantly (t=30.6; $p<0.001$) with an average length of 172.1 mm.

Further analyses of plankton, stomach contents, fresh water age, and scale growth data collected during both surveys will be done to shed additional light on the growth and migration characteristics of juvenile sockeye salmon emigrating from Bristol Bay.

Acknowledgments

The authors wish to thank Captain Charles J. (Jack) Bronson and Captain Mathew and the crew of the F/V *Great Pacific* for their fine efforts on behalf of our research goals. Funding support for the September 1999 cruise was provided by the National Marine Fisheries Service, Alaska Regional Office.

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Table 1. Cruise itineraries for the July 12 – 26 and September 2 – 12 juvenile salmon surveys in the coastal waters of the eastern Bering Sea.

Date	Location/Activity
<u>July 1999</u>	
12-July	Depart Dutch Harbor, run to Cape Cheerful and begin sampling
14-July	Begin sampling Cape Sarichef; enroute Cape Lapin
15-July	Begin sampling Cape Lapin; enroute Moffit Point
16-July	Begin sampling Moffit Point; enroute Cape Lieskof
17-July	Begin sampling Cape Lieskof; enroute Cape Seniavin
18-July	Begin sampling Cape Seniavin; enroute 55.5 km east of C. Seniavin
19-July	Begin sampling 55.5 km east of C. Seniavin; enroute Strogonof Point
20-July	Begin sampling Strogonof Point; enroute Cinder River
21-July	Begin sampling Cinder River; enroute Cape Greig
22-July	Begin sampling Cape Greig; enroute Strogonof Point
23-July	Begin sampling Strogonof Point (repeat sampling nearshore)
24-July	Underway enroute Dutch Harbor
25-July	Arrive Dutch Harbor, begin offloading samples and gear
26-July	Disembark scientists
<u>September 1999</u>	
2-September	Depart Dutch Harbor, enroute 55.5 km east of Cape Seniavin
3-September	enroute 55.5 km east of Cape Seniavin
4-September	Begin sampling 55.5 km east of Cape Seniavin; enroute C. Seniavin
5-September	Begin sampling Cape Seniavin; enroute Cape Rohznof
6-September	Begin sampling Cape Rohznof; enroute Cape Lieskof
7-September	Begin sampling Cape Lieskof; enroute Moffit Point
8-September	Begin sampling Moffit Point; enroute Cape Krenitzin
9-September	Begin sampling Cape Krenitzin; enroute Cape Mordvinof
10-September	Begin sampling Cape Mordvinof; enroute 92.5 km offshore C. Krenitzin
11-September	Begin sampling 92.5 km offshore Cape Krenitzin; enroute Dutch Harbor
12-September	Arrive Dutch Harbor; offload samples and gear; disembark scientists

Table 2. Participating scientists for the July 12 – 26 and September 2 – 12 juvenile salmon surveys in the coastal waters of the eastern Bering Sea.

Scientist	Agency
July 1999	
Edward V. Farley, Jr. (Chief Scientist)	Auke Bay Laboratory, AFSC, NMFS
James M. Murphy	Auke Bay Laboratory, AFSC, NMFS
Christine T. Baier	AFSC, NMFS
Milo D. Adkison	University of Alaska, Fairbanks
Vladimir I. Radchenko	Pacific Research Fisheries Center (TINRO)
September 1999	
Edward V. Farley, Jr. (Chief Scientist)	Auke Bay Laboratory, AFSC, NMFS
Richard E. Haight	Auke Bay Laboratory, AFSC, NMFS
Charles M. Guthrie, III.	Auke Bay Laboratory, AFSC, NMFS
Frank Satterfield	University of Alaska, Fairbanks

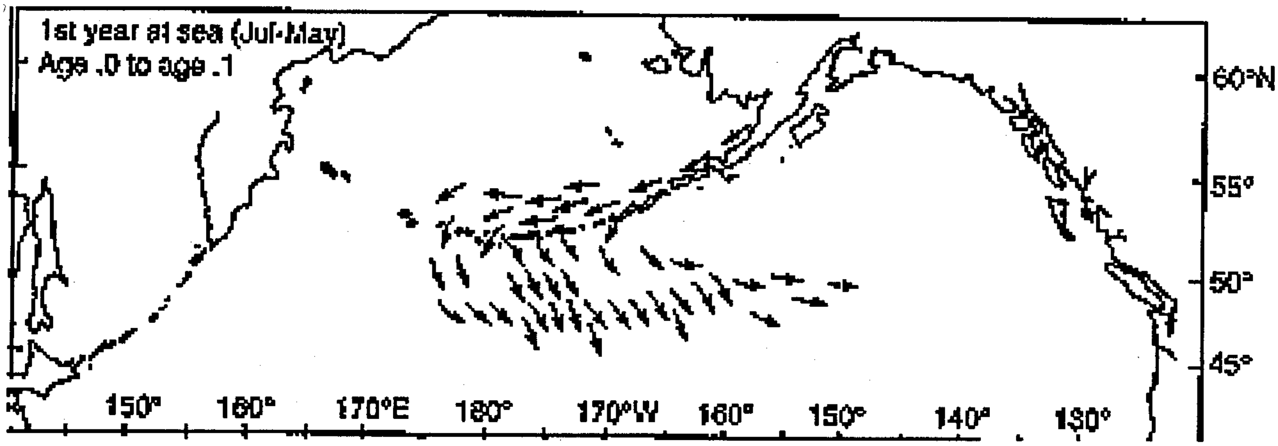

Figure 7. Model of migration of western Alaska sockeye salmon (Adapted from French et al. 1976)