Stock-Structured Distribution of Western Alaska and Yukon Juvenile Chinook Salmon (*Oncorhynchus tshawytscha*) from United States BASIS Surveys, 2002–2007

James M. Murphy[1], William D. Templin[2], Edward V. Farley, Jr.[1], and James E. Seeb[3]

[1]*Ted Stevens Marine Research Institute, Auke Bay Laboratories, Alaska Fisheries Science Center, NOAA Fisheries, 17109 Point Lena Loop Road, Juneau, AK 99801, USA*
[2]*Gene Conservation Laboratory, Division of Commercial Fisheries, Alaska Department of Fish and Game, 333 Raspberry Road, Anchorage, Alaska 99518, USA*
[3]*University of Washington, School of Aquatic and Fishery Sciences, Box 355020, Seattle, WA 98195, USA*

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Abstract: We describe migratory patterns of western Alaska and Yukon Chinook salmon (*Oncorhynchus tshawytscha*) using stock-structured distribution data from United States Bering-Aleutian Salmon International Surveys (BASIS), 2002–2007. Juvenile Chinook salmon were distributed within water depths less than 50 m and their highest densities were found close to river mouths of primary Chinook salmon-producing rivers in the eastern Bering Sea (Yukon, Kuskokwim, and Nushagak rivers) through their first summer at sea. This reflects a later marine dispersal from freshwater entry points than typically found in Gulf of Alaska stream-type Chinook salmon and resulted in the presence of juvenile Chinook salmon in shallow, non-trawlable habitats during the surveys. Juvenile Chinook salmon stock proportions in the northern shelf region (north of 60°N) were: 44% Upper Yukon, 24% Middle Yukon, 31% Coastal Western Alaska, and 1% other western Alaska stock groups. Juvenile Chinook salmon stock proportions present in the southern shelf region (south of 60°N) were: 95% Coastal Western Alaska, 1% Upper Yukon, and 4% other western Alaska stock groups. It is believed that these stock mixtures do not support significant northward migration of stocks from the southern shelf, and reflect limited mixing of salmon from the two production regions during their first summer at sea. Spatial distribution patterns and coded-wire tag recoveries provide evidence that the distribution of Yukon River Chinook salmon extends northward into the Chukchi Sea during their first summer at sea. Although the juveniles present in the Chukchi Sea represent a minor portion of the total Yukon River juvenile population, continued warming of the Arctic could increase the proportion of Yukon River Chinook salmon migrating north into the Chukchi Sea.

Keywords: Bering Sea, Chinook salmon, distribution, migration, stock structure

INTRODUCTION

Migratory corridors used by Chinook salmon (*Oncorhynchus tshawytscha*) and their distribution within the corridors provide key information on the early marine ecology and life-history strategies of juvenile salmon important to their growth and survival (Brodeur et al. 2000). Juvenile Chinook salmon from western Alaska and Yukon, Canada enter the marine waters of the eastern Bering Sea during the spring and summer and migrate along the coast of western Alaska during their first summer in the ocean (Healey 1991). An understanding of the underlying migratory patterns of salmon is also required to interpret and apply research survey data to population studies of Chinook salmon (Farley et al. 2005).

Although much of the historical work on salmon migration has relied on tagging and marking research (Hartt and Dell 1986; Orsi and Jaenicke 1996; Farley et al. 1997; Courtney et al. 2000), genetic methods have expanded the ability of research surveys to define migratory behavior of salmon in the ocean (Seeb et al. 2004; Templin et al. 2005). Recent developments in single nucleotide polymorphism (SNP) markers and genetic baselines provide efficient and accurate assignment of Chinook salmon to freshwater origin (Smith et al. 2005; Templin et al. 2005). SNP data can be collected and scored very rapidly compared to other genetic markers, thus increasing its power and efficiency to discriminate stock origins.

All correspondence should be addressed to J. Murphy.
e-mail: jim.murphy@noaa.gov

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Farley et al. (2005) initially described migratory pathways of juvenile Chinook salmon in the eastern Bering Sea using information on juvenile salmon size distribution. Reconstructing migration corridors from size data capitalizes on the fact that much of the variability in juvenile size reflects the time of ocean entry. Dispersal patterns of juvenile salmon from points of ocean entry are apparent in the spatial distribution of size, with the largest juvenile salmon (earliest out-migrants) distributed the greatest distance from their point of ocean entry. In the following analysis, migratory patterns of juvenile western Alaska and Yukon Chinook salmon are described using information on ocean distributions and freshwater origin from coded-wire tags and genetic stock identification methods.

METHODS

Juvenile Chinook salmon were collected with surface rope trawls during the U.S. Bering-Aleutian Salmon International Survey (BASIS) on the eastern Bering Sea shelf from 2002–2007 (Table 1). Start dates of the survey ranged from August 14 to August 21; end dates ranged from September 20 to October 8 (Table 1). Variation in start and end dates each year reflected changes in vessel availability and survey coverage and design. The initial survey design (2002 and 2003) used transect-based sampling along latitude and longitude lines (Farley et al. 2005). A grid-based sampling design with stations at each degree of longitude and 30 minutes of latitude was used from 2004 to 2007.

Juvenile Chinook salmon and other pelagic fish were collected with surface rope trawls built by Cantrawl Pacific Limited of Richmond, British Columbia (Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.). Trawls were 198 m long, had hexagonal mesh in wings and body, and included a 1.2-cm mesh liner in the codend (Murphy et al. 2003). Trawls were towed at the surface at an average speed of 4.3 knots, resulting in an average vertical mouth opening of 14 m and horizontal mouth opening of 58 m. Sampling depths were slightly deeper than the vertical opening as the center of the trawl often was just below the surface during the trawl deployment. Water depths shallower than 20 m were considered non-trawlable and were not sampled. Nor'eastern Trawl Systems 5-m alloy doors with 60-m bridle lengths were deployed typically 360 m astern of the boat. Buoys were secured to the wing-tips and center of the headrope to help keep the trawl at the surface and wingtip buoy wakes were monitored to ensure the headrope was maintained at the surface during the tow. Trawl speeds were adjusted to keep the trawl at the surface and trawl doors in the water. A Simrad FS900 net sounder was used to monitor the fishing dimensions and trawl geometry during each tow. All trawls were towed astern of the vessel for 30 min at each station. Catch per unit of fishing effort, CPUE, was used to describe salmon spatial distributions and the standardized unit of fishing effort was effort during a 30-min trawl set. Average area swept by the trawl at each station was 0.25 km^2.

Stations were sampled between 07:30–21:00 hours (Alaska Standard Time), and typically four stations were sampled each day. Stations were sampled during daylight with the exception of the first station of each day. The first station of the day was sampled just after sunrise, and occasionally sampling would occur during sunrise depending on the schedule set for vessel operations by the chief scientist. Salmon catch rates from the crepuscular time-period were not significantly different from other daylight samples (Farley et al. in press). Sample dates differed by location due to the order in which stations were sampled during the survey. Average sample dates were estimated with a weighted average date with weights provided by the catch at each station.

Standard research trawl protocols were used to process the trawl catch. All salmon were sorted and counted by spe-

Table 1. Number of surface trawl stations sampled during U.S. BASIS surveys on the eastern Bering Sea shelf by year and vessel, 2002–2007.

Year	Vessel	Start Date	End Date	Number of Trawl Stations
2002	F/V *Sea Storm*	20-Aug-02	07-Oct-02	152
	F/V *Northwest Explorer*	08-Sep-02	06-Oct-02	44
2003	F/V *Sea Storm*	21-Aug-03	08-Oct-03	151
2004	F/V *Sea Storm*	14-Aug-04	30-Sep-04	143
2005	F/V *Sea Storm*	14-Aug-05	06-Oct-05	127
2006	F/V *Sea Storm*	14-Aug-06	20-Sep-06	105
	F/V *Northwest Explorer*	21-Aug-06	04-Sep-06	53
2007	F/V *Sea Storm*	15-Aug-07	08-Oct-07	136
	NOAA Ship *Oscar Dyson*	05-Sep-07	26-Sep-07	50

cies and life-history stage; all juvenile Chinook salmon were examined for a missing adipose fin. Snouts were removed from juvenile Chinook salmon with a missing adipose fin and examined for the presence of a coded wire tag at the Auke Bay Laboratories in Juneau, Alaska. Individual lengths and weights were collected from a subsample of up to 50 Chinook salmon and genetic samples were collected from these fish.

Kriging models implemented in ArcGIS software package (ESRI 2006) were used to construct the spatial distribution map of juvenile Chinook salmon on the eastern Bering Sea shelf. The spatial mean was removed with a local polynomial regression model prior to fitting the Kriging model and the spatial covariance of juvenile Chinook salmon was modeled with a spherical variogram (Cressie 1991). The spatial model was used to estimate the distribution of juvenile Chinook salmon in non-trawlable habitats with the addition of boundary conditions. Boundary conditions were created by adding with zero catch points on land at spatial scales matching the survey sampling grid.

Freshwater stock origins of juvenile Chinook salmon were determined from coded-wire tag (Jefferts et al. 1963) recoveries and from genetic stock identification analysis. Coded-wire tags were assigned to freshwater origin using the coast-wide mark database maintained by the Pacific States Marine Fisheries Commission (http://www.rmpc.org/) and by coded-wire tag release information provided by the Whitehorse Rapids Fish Hatchery (YRJTC 2009).

A coast-wide baseline of 42 SNP genetic markers for Chinook salmon (updated from Templin et al. 2005) was used to assign freshwater origin of juvenile Chinook salmon. SNP data were obtained from 1,356 juvenile Chinook salmon collected during 2002–2006 following the methods of Seeb at al. (2009), and stock mixtures were estimated for three locations on the eastern Bering Sea shelf. Mixed stock proportions at each location were estimated using conditional maximum likelihood models implemented in the SPAM 3.7 mixed-stock software program (Debevec et al. 2000). Accuracy of mixed stock assignment to freshwater origins considered in this analysis was greater than 90% using the 42-SNP baseline (Templin et al. 2005).

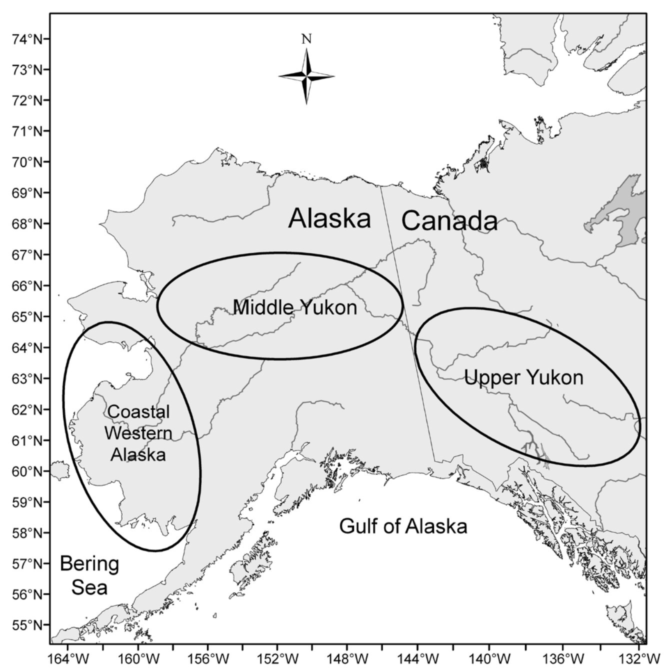

Fig. 1. Approximate locations of regional genetic stock groups of juvenile Chinook salmon (Coastal Western Alaska, Middle Yukon, and Upper Yukon) captured during U.S. BASIS surface trawl surveys on the eastern Bering Sea shelf.

Chinook salmon outside of the eastern Bering Sea were not assumed to be present in the area sampled by the U.S. BASIS survey during their first summer at sea (juvenile life-history stage); therefore, only Chinook salmon stocks from eastern Bering Sea river systems were considered in the mixed stock analysis. Stock groups included in the analysis were: the Upper Yukon River stock group, the Middle Yukon River stock group, the Coastal Western Alaska stock group, and an 'Other' stock group (Fig. 1). The Coastal Western Alaska stock group included the Lower Yukon Chinook salmon stocks and all other western Alaska stock groups outside of the Yukon River except the Upper Kuskokwim River and North Alaska Peninsula stock groups. For simplicity, these two stock groups were combined into a single 'Other' stock group. The Lower Yukon stock group included Alaskan tributary streams draining the Andreafsky Hills and Kaltag Mountains; the Middle Yukon stock group included Alaskan tributary streams in the upper Koyukuk River and Tanana River basins; the Upper Yukon stock group included Canadian tributary streams draining the Pelly and Big Salmon mountains (Lingnau and Bromaghin 1999).

Juvenile mixtures in the northern shelf region (north of 60°N) were compared with expected adult stock mixtures in the Yukon River. Expected adult stock mixtures were estimated by the average mixtures present in historical and recent commercial and subsistence harvests in the Yukon River (DuBois and DeCovich 2008; Bue and Hayes 2009). These estimates were not corrected for potential stock selective harvest.

RESULTS

Juvenile Chinook salmon were primarily distributed within water depths less than 50 m through their first summer at sea (middle of August through the middle of October). The highest densities of juvenile Chinook salmon were found close to river mouths of primary Chinook salmon-producing rivers in the eastern Bering Sea (Yukon, Kuskokwim, and Nushagak rivers) (Fig. 2). Juvenile Chinook salmon were distributed as far north as the Chukchi Sea and the southern extent of their distribution was along the north shore of Bristol Bay. The migratory corridor of juvenile Chinook salmon was broader in the northern shelf (north of 60°N) than in the

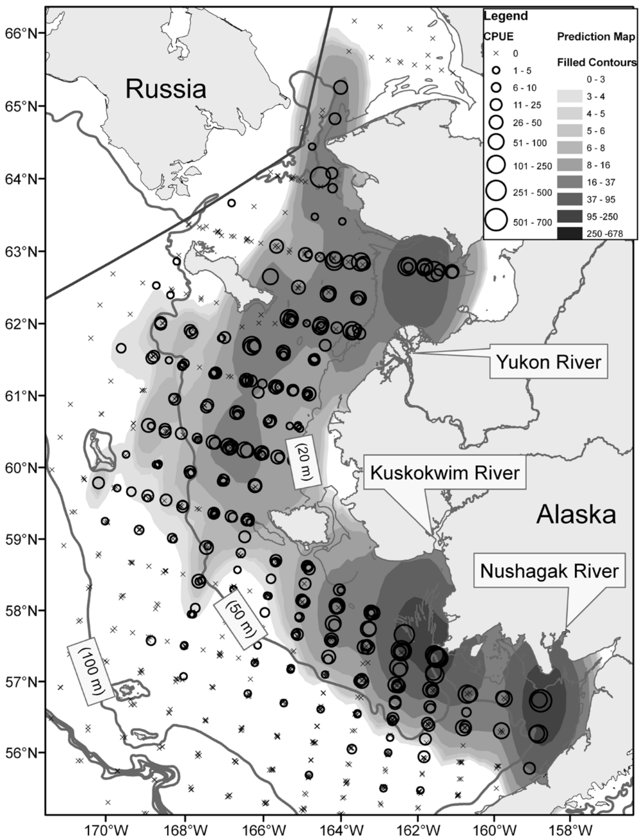

Fig. 2. Distribution of juvenile Chinook salmon during U.S. BASIS surface trawl surveys on the eastern Bering Sea shelf (mid August to early October), 2002–2007. Distribution is based on catch per unit of effort (CPUE) with a 30-min trawl haul used as the standard unit of effort. Individual trawl catches are overlaid on the CPUE prediction surface from a Kriging spatial model. Contours are shaded at geometric intervals of the prediction surface.

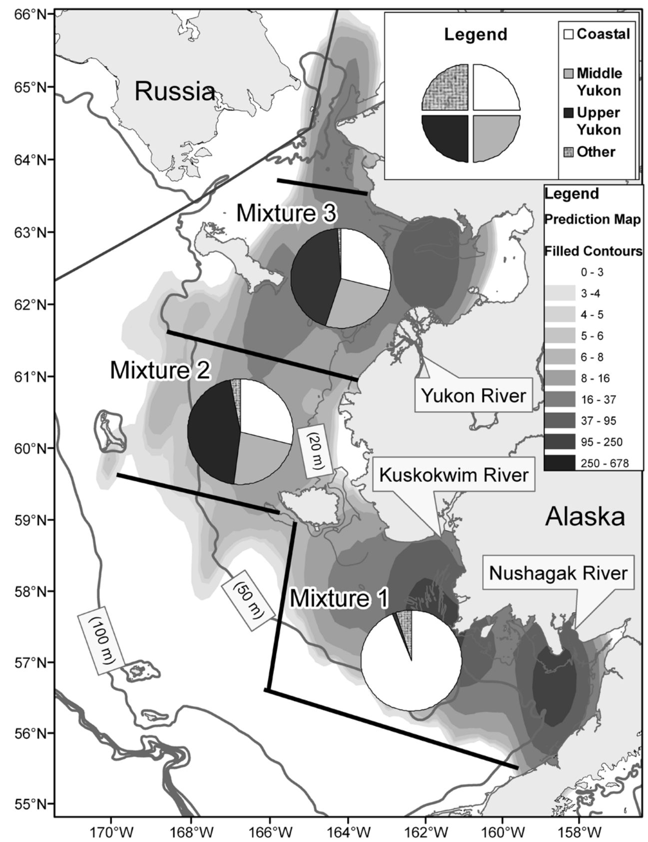

Fig. 3. Genetic stock mixtures of juvenile Chinook salmon (Coastal Western Alaska, Middle Yukon, Upper Yukon, and 'other' stock groups) captured during U.S. BASIS surface trawl surveys on the eastern Bering Sea shelf (mid August to early October), 2002–2006. Mixtures are overlaid on a map of juvenile Chinook salmon distribution and black bars identify the spatial extent of samples used for each mixture. Genetic mixtures are overlaid on the CPUE prediction surface from a Kriging spatial model. Contours are shaded at geometric intervals of the prediction surface.

Table 2. Estimated stock mixtures of juvenile Chinook salmon (with 95% confidence intervals) collected during U.S. BASIS surface trawl surveys on the eastern Bering Sea shelf by region and location, 2002–2006. Average sample dates and DNA sample sizes are included.

Stock Mixture	Region	Location	Average Sample Date	Sample Size	Stock Group			
					Coastal Western Alaska	Middle Yukon	Upper Yukon	Other
1	Southern Bering Shelf	< 167°W	24-Aug	819	0.95 (0.89–0.98)	0.00 (0.00–0.00)	0.01 (0.00–0.01)	0.04 (0.02–0.11)
2	Northern Bering Shelf	60°N<>62°N	24-Sep	238	0.31 (0.23–0.37)	0.23 (0.15–0.30)	0.44 (0.37–0.52)	0.02 (0.00–0.08)
3	Northern Bering Shelf	62°N<>64.5°N	10-Sep	299	0.30 (0.25–0.35)	0.26 (0.20–0.32)	0.43 (0.37–0.50)	0.01 (0.00–0.03)
2 & 3	Northern Bering Shelf	60°N<>64.5°N	14-Sep	537	0.31 (0.26–0.35)	0.24 (0.20–0.29)	0.44 (0.40–0.49)	0.01 (0.00–0.03)

southern shelf region. Peak densities of juvenile Chinook salmon occurred in the shallowest water depths sampled during the survey. Significant numbers of juvenile Chinook salmon were estimated to be present in water depths shallower than could be sampled by the trawl gear (20 m).

Average sample dates of the genetic mixtures differed due to the order in which stations were sampled during the survey (Table 2). The average sample date of mixtures 1, 2, and 3 were: August 24, September 24, and September 10, respectively. The average sample date of mixtures 2 and 3 combined was September 16.

Stock mixtures differed by region and location (Table 2, Fig. 3). In the southern Bering Sea shelf (mixture 1), stock proportions were: 95% Coastal Western Alaska, 1% Upper Yukon, and 4% other western Alaska stock groups. In the northern Bering Shelf, mixture 2 contained 44% Upper Yukon, 23% Middle Yukon, and 31% Coastal Western Alaska stocks, and 2% other western Alaska stock groups. Mixture 3 was similar to mixture 2 with 43% Upper Yukon, 26% Middle Yukon, 30% Coastal Western Alaska, and 1% other western Alaska stock groups. Stock proportions from mixtures 2 and 3 combined, were 44% upper Yukon, 24% Middle Yukon, 31% Coastal Western Alaska stocks, and 1% other Western Alaska stock groups.

Stock proportions between juvenile populations and adult harvests were similar enough to discount significant bias due to incomplete sampling of the juvenile population within the northern shelf region. The proportion of the Coastal Western Alaska stock group in the juveniles from the northern shelf region (mixtures 2 and 3 combined, 31%, SD = 3%) was slightly higher than the proportion in the harvest (21%, SD = 8%), but within the range expected for Yukon River harvests (DuBois and DeCovich 2008). The proportion of the Middle Yukon River stock group in the juvenile population (24%, SD = 3%) was similar to the proportion observed in historic harvests (23%, SD = 10%). The proportion of the Upper Yukon stock group in the juvenile population (44%, SD = 3%) was lower than the average proportion in historic harvests (56%, SD = 8%), but higher than the proportion in recent harvests. The Upper Yukon stock group comprised 37% and 36% of the total harvest in 2007 and 2008, respectively (Bue and Hayes 2009).

Coded-wire tags all matched tag codes from the Whitehorse Rapids Fish Hatchery located near Whitehorse, Yukon. Coded-wire tag codes from juvenile Chinook salmon released by the Whitehorse Rapids Fish Hatchery in 2002 included release location codes (Table 3). Tag codes from 2007 only included information on agency and year of release. However, as no other tagged Canadian juvenile Chinook entered the ocean in the Bering Sea in 2007, it was possible to assign origin to the Whitehorse Rapids Fish Hatchery.

Coded-wire tags were recovered at the mouth of the Yukon River and just south of the Bering Strait (Fig. 4). Coded-wire tags from 2002 were recovered near the mouth of the Yukon River at 63°N and at 64.1°N. Coded-wire tags recovered from 2007 were all recovered just south of the Bering Strait at 65.2°N, confirming the presence of a northward migration corridor for juvenile Yukon Chinook salmon.

All coded-wire tagged juveniles were age-0 (or fall-type Chinook salmon), a known life-history feature of Chinook

Table 3. Coded-wire tag recoveries from juvenile Chinook salmon captured during U.S. BASIS surface trawl surveys on the eastern Bering Sea shelf, 2002–2007. Release information provided by the Whitehorse Rapids Fish Hatchery (YRJTC, 2009).

Freshwater Origin	Tag Code	Release Data		Recovery Data				
		Date	Weight (g)	Date	Latitude	Longitude	Length (mm)	Weight (g)
Whitehorse Rapids Hatchery: Michie Creek	185061	2-Jun-02	3.2	4-Oct-02	63.0°N	166.0°W	155	49
Whitehorse Rapids Hatchery: Michie Creek	185106	10-Jun-02	3.2	3-Oct-02	64.1°N	164.5°W	193	79
Whitehorse Rapids Hatchery: Wolf Creek	185102	2-Jun-02	3.1	3-Oct-02	64.1°N	164.5°W	153	43
Whitehorse Rapids Hatchery	18	2007	--	13-Sep-07	65.2°N	168.1°W	176	58
Whitehorse Rapids Hatchery	18	2007	--	13-Sep-07	65.2°N	168.1°W	125	18
Whitehorse Rapids Hatchery	18	2007	--	13-Sep-07	65.2°N	168.1°W	179	58

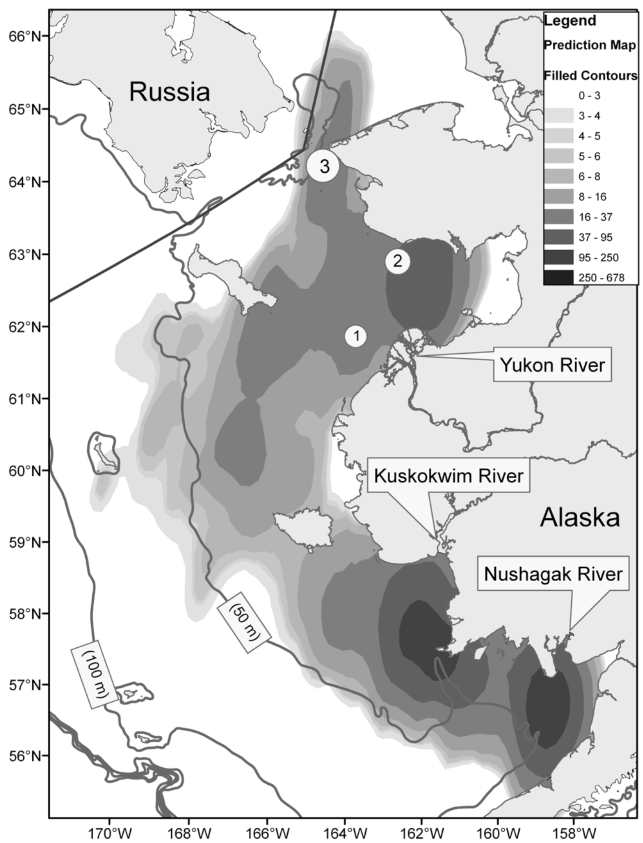

Fig. 4. Locations of coded-wire tag recoveries of Whitehorse Rapids Fish Hatchery Chinook salmon from the Yukon River during U.S. BASIS surface trawl surveys on the eastern Bering Sea shelf (mid August to early October), 2002–2007. Circles indicate coded-wire tag recovery locations and are overlaid on a map of juvenile Chinook salmon distribution. Numbers in each circle indicates the number of coded-wire tags recovered at each location and are overlaid on the CPUE prediction surface from a Kriging spatial model. Contours are shaded at geometric intervals of the prediction surface.

salmon produced from the Whitehorse Rapids Fish Hatchery. The size of hatchery juveniles (125–193 mm; 18–79 g) were significantly smaller than the average size of juvenile Chinook salmon captured during the survey (213 mm, 127 g), and hatchery juveniles still had visible parr marks at the time of capture (average date of September 10). The presence of parr marks on hatchery juveniles indicates an ocean entry date much later than most wild juvenile Chinook salmon on the eastern Bering Sea shelf and is consistent with their classification as ocean-type Chinook salmon.

DISCUSSION

The estuarine and early ocean habitats of juvenile salmon in the Bering Sea differ from juvenile salmon habitats in the Gulf of Alaska. Juvenile salmon occupy a broad shallow shelf with relatively stable waters in the Bering Sea. In the Gulf of Alaska, juvenile salmon occupy habitats ranging from a network of narrow corridors associated with fjords in southeast Alaska, to the narrow shelf and highly dynamic waters of northern California (Brodeur et al. 2000; Orsi et al. 2000). Migratory corridors of juvenile salmon in summer are largely thought to be constrained to epipelagic waters over the continental shelf once they reach the open ocean in the Gulf of Alaska (Brodeur et al. 2000; Orsi et al. 2000; Fisher et al. 2007). Juvenile salmon migratory corridors in all open ocean regions are most likely defined by oceanographic, not bathymetric features; however, the close association of these features in the Gulf of Alaska (Mundy 2005) often results in the use of the continental shelf to describe juvenile salmon migratory corridors. The broad continental shelf of the Bering Sea provides the opportunity to investigate biological and physical features such as water mass types and frontal regions that structure migratory pathways of juvenile salmon.

Juvenile Chinook salmon were primarily distributed within water depths < 50 m throughout their first summer at sea (middle of August through the middle of October) and the highest densities of juvenile Chinook salmon were found close to river mouths of primary Chinook salmon-producing rivers in the eastern Bering Sea (Yukon, Kuskokwim, and Nushagak rivers). This reflects a later dispersal from freshwater entry points than typically found in Gulf of Alaska stream-type Chinook salmon (Fisher et al. 2007). This is likely the effect of later ocean entry dates and slower marine dispersal rates of juvenile Chinook salmon on the eastern Bering Sea shelf.

Foraging behavior of salmon within the Coastal Domain may play a key role in defining juvenile Chinook salmon habitat and dispersal rates during their first summer at sea. The Coastal Domain is typically found in water depths < 50 m on the eastern Bering Sea Shelf (Schumacher and Stabeno 1998) and is associated with reduced water column stability, tight pelagic-benthic coupling, and high benthic productivity (Grebmeier et al. 2006). These structural components of the Coastal Domain favor forage fish species such as capelin and Pacific sand lance, which are the principal prey of juvenile Chinook salmon (Farley et al. in press). It is possible that feeding behavior of Chinook salmon on these forage fish species may be contributing to a delayed dispersal from the Coastal Domain. An apparent preference for the Coastal Domain is also seen in coho salmon (Farley et al. 2005) which also preferentially feed on the forage fish species in the Coastal Domain (Farley et al. in press).

The adequacy of the U.S. BASIS survey design for juvenile Chinook salmon populations differed by region. The broad migratory corridor of juvenile Chinook salmon and later survey sampling dates in the northern Bering Shelf region resulted in most juvenile Chinook salmon from this region present within trawlable habitats (> 20 m). The narrow migratory corridor and earlier sampling dates in the southern shelf region resulted in a higher proportion of the juvenile salmon population present in non-trawlable habitats. The inability to distinguish between primary stock groups contributing to the southern shelf index area also limits our ability to evaluate how well the survey reflects juvenile Chinook salmon stocks in this region.

Stock mixtures of juvenile salmon did not support significant northward migration of stocks from the southern shelf, reflecting limited mixing of salmon from different production regions during their first summer at sea. Juvenile Chinook salmon in the southern region were primarily from the Coastal Western Alaska stock group (95%). Therefore, the presence of juveniles from the southern region would increase the proportion of juvenile Chinook salmon assigned to the Coastal Western Alaska stock group. Similarity in juvenile salmon stock mixtures from both spatial strata in the northern region indicates that if juveniles from the southern shelf region were migrating north, they would need to be equally present in both northern spatial strata. This is unlikely, given the apparent dispersal rates of juvenile Chinook salmon from the southern region. Comparisons between stock proportions of the juvenile population in the northern shelf region and Yukon River harvests also did not support significant northward migration of southern stocks. If significant numbers of juvenile Chinook salmon from southern shelf were migrating north, the estimated proportions of the Coastal Western Alaska stock group would be significantly higher in the northern shelf region than expected for Yukon River Chinook salmon. The proportion of Coastal Western Alaska stocks in the northern shelf region was within the range expected for Yukon River Chinook salmon. Stock differences between the juveniles and historic harvests are most likely the result of reduced production of the Upper Yukon stock group relative to historic returns to the Yukon River (Bue and Hayes 2009). Limited northward migration of juvenile Chinook salmon from the southern shelf region is consistent with the interpretation of size and distribution data summarized by Farley et al. (2005).

Coded-wire tag recoveries of Yukon River Chinook salmon near the Bering Strait provide evidence that Yukon River Chinook salmon distributions can extend northward into the Bering Strait. The combined pattern of juvenile Chinook salmon distribution and coded-wire tag recoveries (Fig. 4) suggests that Yukon River Chinook salmon distributions can also extend into the Chukchi Sea. Although the proportion of Yukon River Chinook salmon that are believed to migrate into the Chukchi Sea is small relative to their total marine distribution, anticipated changes in Arctic climate and sea-ice levels could alter the proportion of Yukon River salmon migrating into the Chukchi Sea (Moss et al. 2009). The northward extension of juvenile Chinook salmon distribution into the Chukchi Sea was primarily due to catches in 2007—a year with record loss of Arctic sea ice and an exceptionally warm summer (Moss et al. 2009). Northward advection or migration of Yukon River Chinook salmon is in contrast to the lack of significant northward advection or migration observed in juvenile Chinook salmon from the southern shelf region. This may reflect differences in marine habitats (water depths, freshwater discharge levels, seasonal currents, surface temperatures, prey fields, e.g.) or simply differences in the behavior or life-history of juvenile Chinook salmon from the two regions.

Life-history differences between wild and hatchery fish can result in different marine distributions; therefore it is not appropriate to characterize the distribution of Yukon River stocks with hatchery coded-wire tag recoveries alone. Stock identification data are needed to adequately describe marine distributions. Wild Yukon River Chinook are characterized as stream-type Chinook salmon (also known as spring-type as they generally enter the marine habitat in the spring) (Gilbert 1922). Hatchery Yukon River Chinook salmon are characterized as ocean-type Chinook salmon (also known as fall-type as they enter the marine habitat in the fall), which have a freshwater age of zero (age-0) (YRJTC 2009). However, life histories of wild and hatchery Yukon River Chinook salmon are not completely unique. Several unmarked or wild juvenile Chinook salmon were similar in size to or smaller than hatchery Chinook salmon and had visible parr marks during September. This suggests that ocean-type or age-0 juveniles are present in wild populations; although, they are believed to represent only a minor portion of the total juvenile population. Size and timing of ocean entry of Yukon River Chinook salmon summarized by Martin et al. (1987) also suggests the presence of age-0, -1, and older Chinook salmon in wild Yukon River stocks. The presence of freshwater age-0 Yukon River Chinook salmon in wild populations emphasizes the importance of freshwater age plasticity in stream-type Chinook salmon as part of their natural life-history variation and not simply an artifact of hatchery rearing (Beckman and Dickhoff 1998).

The following conclusions can be made concerning the U.S. BASIS survey data as it applies to juvenile Chinook salmon populations on the eastern Bering Sea shelf. Juvenile Chinook salmon are present in non-trawlable habitats; therefore, the effect of non-trawlable habitats needs to be considered when applying survey data to juvenile Chinook salmon populations, particularly in the southern shelf region. Limited mixing of juvenile Chinook salmon from different production regions (northern and southern shelf regions) is thought to occur during their first summer at sea. However, stock mixtures of juvenile Chinook salmon within each region will be needed to evaluate the status of managed stock groups. Although Yukon River Chinook salmon stocks can extend northward into the Chukchi Sea, the proportion of Yukon River Chinook salmon present in the Chukchi Sea is small relative to the total marine distribution of juvenile Yukon River salmon. However, it is also important to recognize that changes in Arctic climate and the loss of sea ice could increase the proportion of Yukon River Chinook salmon present in the Chukchi Sea during their first summer at sea.

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