Genetic research provides insight into the production and behavior of western Alaska chum salmon

Chris Kondzela, Jeffrey R. Guyon, and Jim Murphy

Introduction and objectives

In western Alaska, chum salmon (*Oncorhynchus keta*) are critical for subsistence, commercial, and cultural reasons. Over the last few decades, declines in chum salmon returns in some western Alaskan drainages prompted various disaster declarations by the State of Alaska and federal agencies. In addition, chum salmon fisheries on the Yukon and Kuskokwim Rivers, two of the largest chum salmon production drainages in western Alaska, have been complicated in recent years by various restrictions designed to limit the take of Chinook salmon, which are currently at very low abundance.

Sorting juvenile salmon from trawl haul. SECM Project

Little is known about the survival of juvenile Yukon River chum salmon in their freshwater or saltwater environments.

The two distinct Yukon River chum salmon life-history types, an earlier and typically more abundant summer run and a later fall run, are managed by the Alaska Department of Fish and Game (ADF&G) to provide escapement and maximize harvest opportunity. Summer-run chum salmon generally spawn in the lower to middle reaches of the Yukon drainage, whereas fall-run chum salmon are typically larger and generally spawn in spring-fed regions of the middle to upper reaches in Alaska and Canada. The summer run of chum salmon has averaged 1.8 million fish between 2000 and 2012, and the fall run has averaged 864,000 fish over the same time period, although there is variation in the two run strengths between years. Concern about low fall-run chum salmon abundance in some years has resulted in reduced subsistence fishing opportunities and has created challenges in fulfilling treaty obligations with Canada that specify escapement objectives.

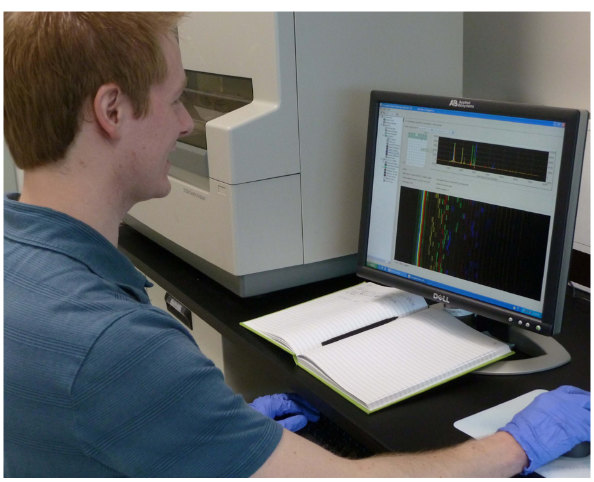
Little is known about the survival of juvenile Yukon River chum salmon in their freshwater or saltwater environments. Juvenile chum salmon out-migrate from the Yukon River in the spring and are found in the pelagic waters on the eastern Bering Sea shelf during summer and fall months. Juvenile chum salmon have been collected as part of annual U.S. Bering-Aleutian Salmon International Surveys (BASIS) in the eastern Bering Sea since 2002. A previous genetic analysis of the 2002 juvenile chum salmon based on allozyme markers determined that a substantial proportion of juvenile chum salmon samples collected in this area were from the Yukon River; however, samples from other years remained unanalyzed.

With support from the Arctic-Yukon-Kuskokwim Sustainable Salmon Initiative and the Alaska Sustainable Salmon Fund, we genetically analyzed juvenile chum salmon samples collected on the 2003–07 BASIS cruises. Our study had three objectives. First, with genetic mixed-stock analyses, determine the extent of stock contributions of juvenile chum salmon on the eastern Bering Sea shelf off the mouth of the Yukon River and compare the distribution across years. Second, develop a relative abundance index of summer- and fall-run Yukon River juvenile chum salmon on the eastern Bering Sea shelf. Third, examine the potential to correlate juvenile relative abundances with adult returns for summer and fall Yukon River chum salmon runs. A full report of this study is available online at http://www.akssf.org/Default.aspx?id=2420).

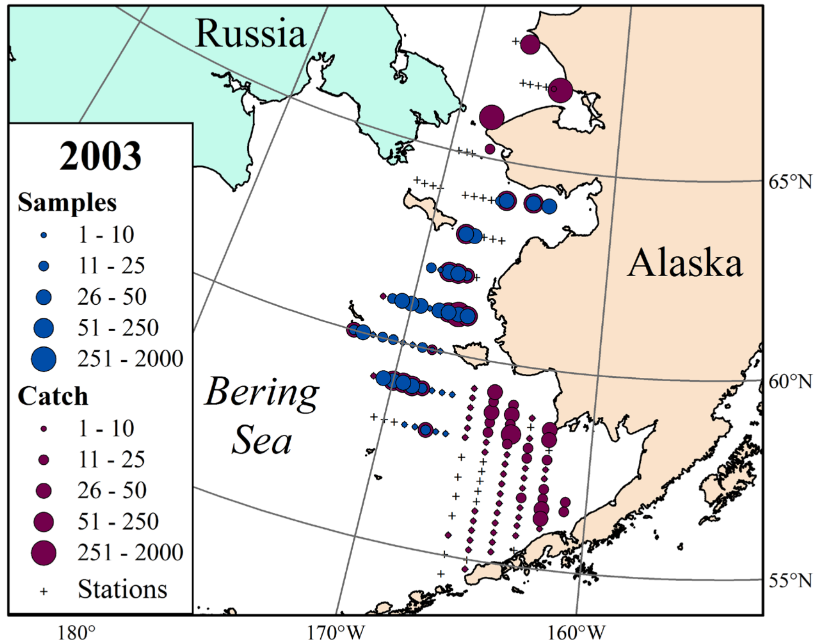
Methods

Sample and data collection, and mixed-stock analyses

Tissue samples and catch data from the U.S. BASIS cruises were provided by the Alaska Fisheries Science Center's (AFSC) Ecosystem Monitoring and Assessment Program at Auke Bay Laboratories. Juvenile chum salmon samples were collected on the eastern Bering Sea shelf during late summer-early fall from 2003 through 2007 (Fig. 1). Fish were collected with a midwater rope trawl that was towed at or near the surface during daylight hours; all tows lasted 30 minutes and covered 2.8 to 4.6 km. The genetic analysis of the 2003–07 juvenile chum salmon focused on samples collected between approximately lat. 58° and 64°N. This latitudinal range encompasses an area for which juvenile chum salmon are likely to be from the Yukon River, and relative abundances between summer- and fall-run juvenile indices may more likely correlate with adult Yukon River returns. DNA was extracted from 5,002 juvenile chum salmon. Genotypes were obtained for 11 of the genetic markers (microsatellite loci) represented in the coastwide chum salmon genetic baseline. The genotypes were used for stock composition estimates that were determined with a Bayesian algorithm. The stock composition estimates were the proportion of each grouping of baseline populations that contributed to the mixture of juvenile chum salmon samples of unknown origin.



Reviewing Genetic Analyzer results. Chris Kondzela



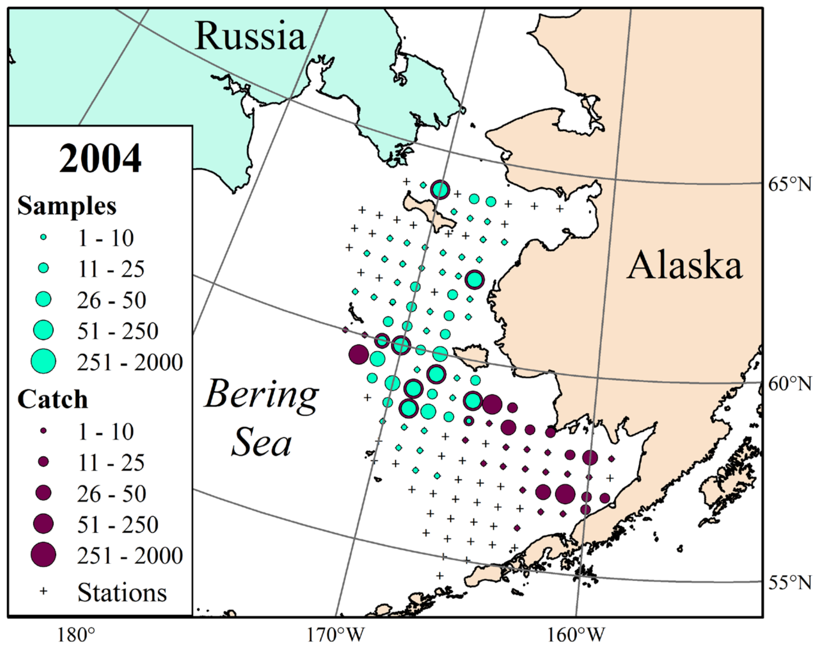
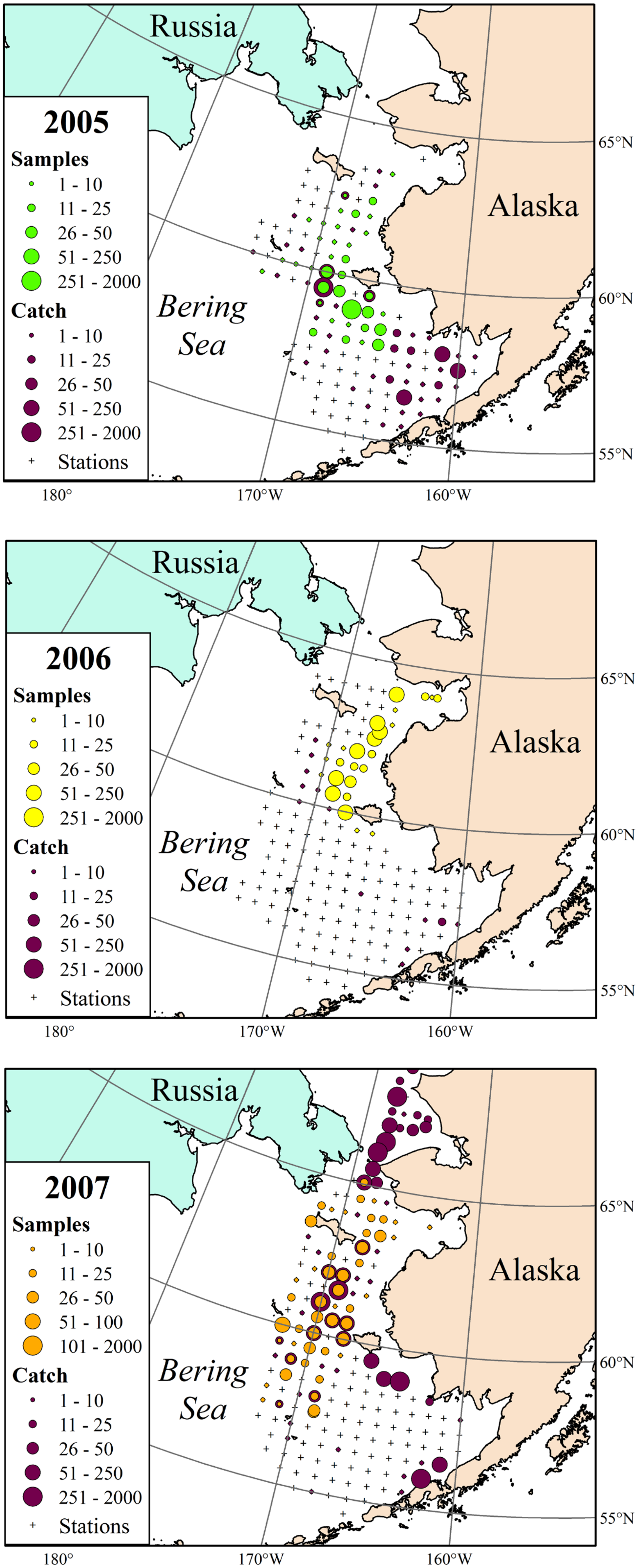


Figure 1. Sample spatial distribution of juvenile chum salmon collected in the eastern Bering Sea from the 2003–07 BASIS cruises. Samples that were genotyped are designated as "Samples" whereas the total catch from the survey is designated as "Catch." Stations surveyed with no juvenile salmon caught in the sample are designated with a "+".

Juvenile chum salmon samples were collected on the eastern Bering Sea shelf during late summer-early fall from 2003 through 2007

Figure 1. Continued.

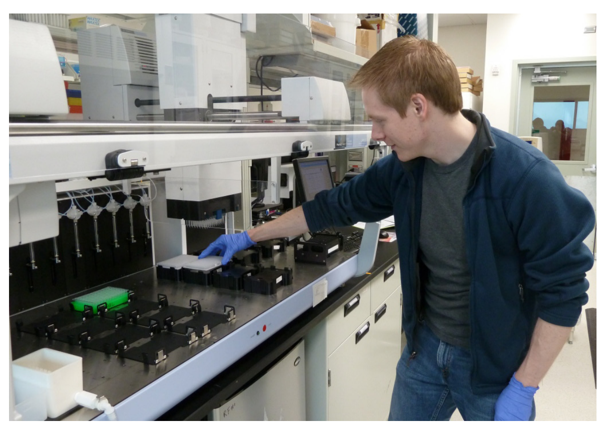


Baseline evaluation

A subset of the coastwide chum salmon baseline was used to develop a western Alaska specific baseline, which was then evaluated to determine finer-scale regional population groupings for stock composition analyses of the juvenile chum salmon mixtures. Population genetic structure of this western Alaska baseline was examined in two ways. First, a principle coordinate analysis (PCO) of genetic distances of baseline populations was completed from genetic marker allele frequencies. Second, baseline simulation analyses were performed to evaluate the effectiveness of the baseline to allocate stocks to the correct regions. Simulation analyses with baseline population resampling were performed by reallocating hypothetical mixtures of 400 fish from a single region to determine the percentage that reallocated back to the correct region.

Yukon River fall-run component

Adult return estimates by age-class for Yukon River chum salmon for years 2000–12 were provided by the ADF&G. To follow brood-year returns, the adult returns were summed for age-3 through age-6 for both summer- and fall-run fish. A relative abundance index for Yukon River fall-run adult chum salmon by brood-year was then computed by dividing the proportion of fall-run chum salmon by the total Yukon River chum salmon return. For the juvenile chum salmon samples collected at sea, the yearly proportions of fall-run fish were determined by dividing the fall-run genetic composition estimate by the total Yukon River genetic composition estimate (summer plus fall). A correlation analysis was performed to determine if there was a relationship between the relative proportion of Yukon River fall-run juveniles collected at sea and 1) the relative proportions of fall-run adults that produced the juveniles, or 2) the relative proportions of fall-run adult brood-year returns.



Loading DNA onto PCR plate with robotic equipment. Chris Kondzela

Results

Genotyping

Most of the juvenile chum salmon samples analyzed were successfully genotyped for 8 or more of the 11 loci (Table 1). Samples genotyped for less than 8 loci were removed from analysis. Quality control of sample handling and genotyping indicated a low discrepancy rate of 0.4%.

Table 1. Number of successfully genotyped juvenile chum salmon samples that were collected in the eastern Bering Sea during 2003–2007 BASIS cruises.

Year	Genotyped number	Collection date
2003	1,069	8/21-10/8
2004	887	8/27–9/28
2005	794	8/15–10/5
2006	1,011	9/3–9/20
2007	1,113	9/5–10/6
Total	**4,874**	

Microsatellite baseline – coastwide groupings

The coastwide chum salmon microsatellite baseline was used to perform stock composition analysis. This baseline consists of 381 populations that we aggregated into six large stock groupings—Southeast Asia, Northeast Asia, Coastal Western Alaska, Upper/Middle Yukon River, Southwest Alaska, and the Gulf of Alaska/Pacific Northwest (GOA/PNW) (Fig. 2). To evaluate the ability of the 11 microsatellite markers to effectively separate the six regional groupings in mixed-stock analyses, simulations were performed with baseline resampling. The baseline reallocated stocks with a high degree of accuracy indicating that stock composition estimates derived from the use of this baseline are highly accurate (Table 2).

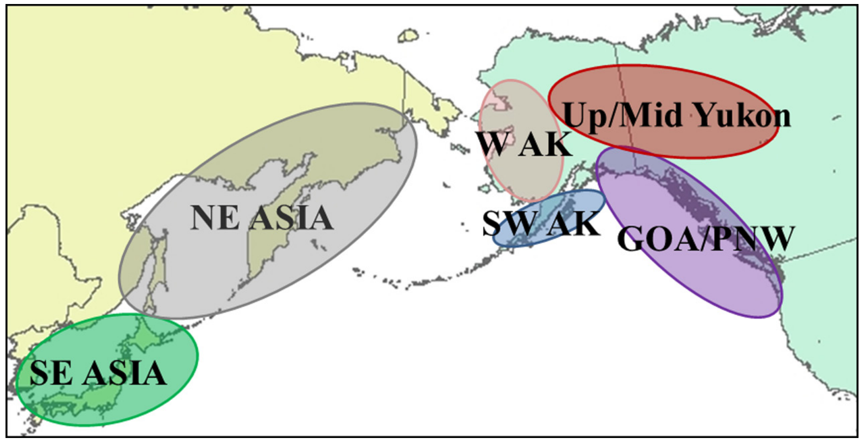


Figure 2. The six large regional groupings of spawning chum salmon stocks from throughout the Pacific Rim: Southeast (SE) Asia; Northeast (NE) Asia; Coastal Western Alaska (W AK); Upper/Middle Yukon River (Up/Mid Yukon); Southwest Alaska (SW AK); and the Gulf of Alaska/Pacific Northwest (GOA/PNW).

Table 2. Coastwide chum salmon baseline evaluation with simulated mixtures in which 100% of the samples were derived from a single regional grouping (read down columns). Correct allocations highlighted in bold font.

Grouping	SE Asia	NE Asia	Coastal West AK	Up/Mid Yukon	SW Alaska	GOA-PNW
SE Asia	**0.873**	0.041	0.004	0.001	0.015	0.003
NE Asia	0.036	**0.835**	0.008	0.002	0.047	0.007
Coastal West AK	0.008	0.055	**0.960**	0.059	0.040	0.002
Up/Mid Yukon	0.000	0.002	0.010	**0.934**	0.001	0.000
SW Alaska	0.002	0.007	0.004	0.000	**0.819**	0.003
GOA-PNW	0.016	0.045	0.010	0.002	0.070	**0.977**

Stock composition estimates – coastwide groupings

Yearly stock composition estimates were made with the coastwide chum salmon baseline and six large regional groupings for samples collected between long. 172.50° and 166.75°W and lat. 58° and 63°N (Fig. 3). More than 95% of the 2003–07 juvenile chum salmon samples were from the Coastal Western Alaska and Upper/Middle Yukon regions. Because most of the fish were from these two regions, a more parsimonious baseline was selected for additional stock composition analyses with finer-scale regional groupings.

The coastwide chum salmon microsatellite baseline was used to perform stock composition analysis.

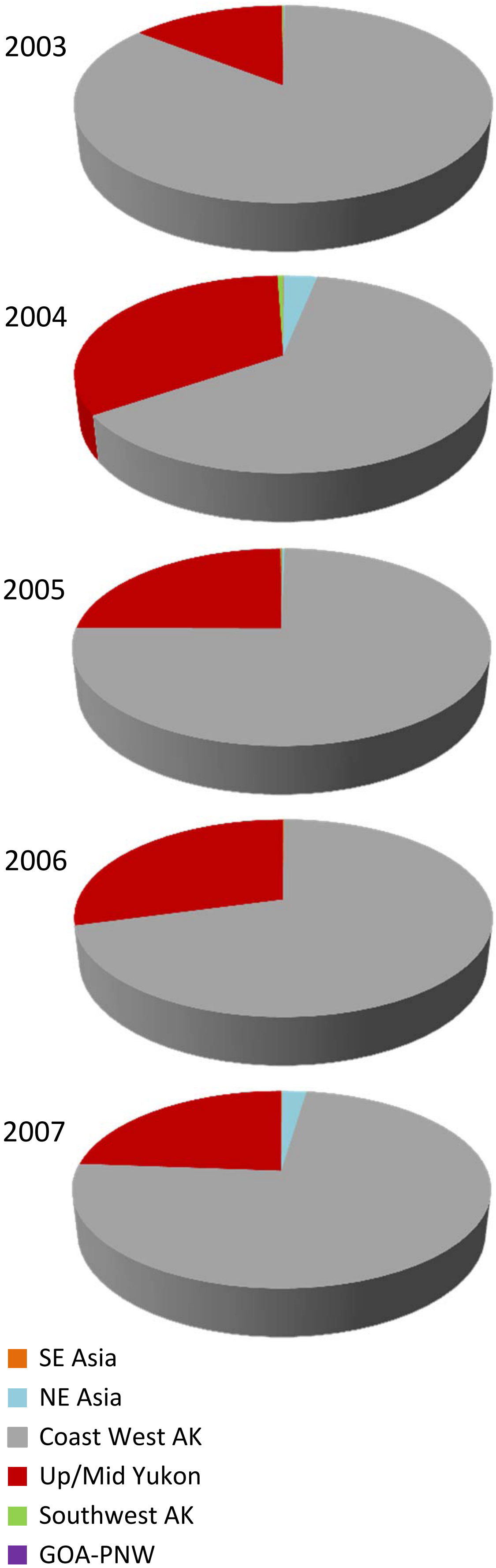


Figure 3. Regional stock composition estimates for juvenile chum salmon collected between lat. 58° and 63°N in the eastern Bering Sea during the summer/fall 2003-2007 BASIS cruises.

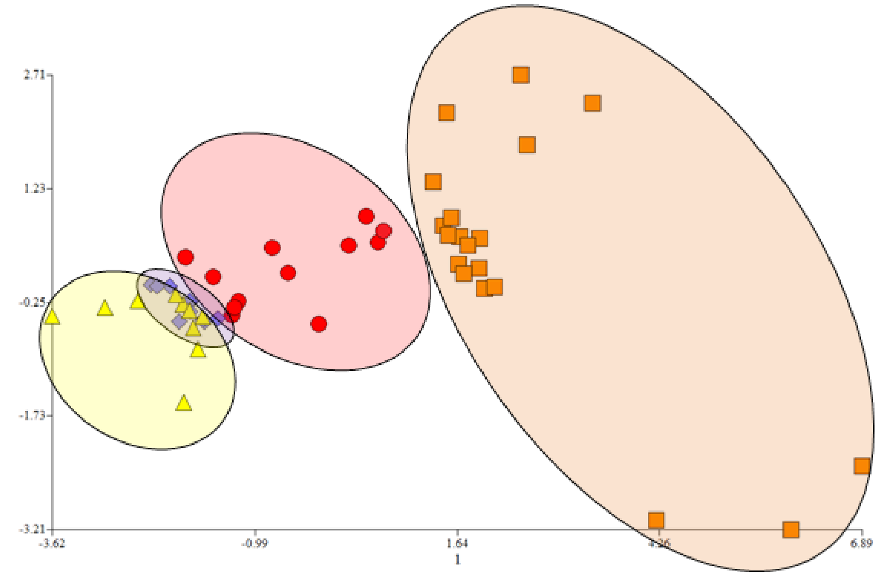


Figure 4. Principal coordinate analysis for the 51 western Alaska and Yukon River populations separated into four temporal-spatial groupings. Yukon Summer (red circles), and Yukon Fall (orange squares), Norton Sound (purple diamonds), and Kuskokwim/NE Bristol Bay (yellow triangles).

Microsatellite baseline – western Alaska/Yukon groupings

The preponderance of juveniles in the eastern Bering Sea of western Alaska origin led to additional analyses to determine the suitable number of stock groupings for the 51 populations in western Alaska between Norton Sound and northeastern Bristol Bay, including the Yukon River drainage. The finer-scale population groupings were determined from principal coordinate analysis based on genetic distances and State of Alaska salmon management areas, and were evaluated with baseline simulation analyses. On the first two principal coordinates, the Yukon River summer-run (red circles) and fall-run (orange squares) chum salmon populations separate (Fig. 4). All of the Norton Sound populations (purple diamonds) clustered tightly together, but the Kuskokwim/NE Bristol Bay populations (yellow triangles) clustered more loosely and many overlap with the Norton Sound populations (Fig. 4). With these four western Alaska chum salmon stock groupings (Fig. 5), baseline simulation analyses showed that the baseline reallocated three of the four groupings (Yukon summer, Yukon fall, and Norton Sound) with a high degree of accuracy, but there was substantial misallocation of the Kuskokwim/NE Bristol Bay grouping to other coastal western Alaska groupings (Table 3). Stock composition analyses performed with these baseline groupings may underestimate the contribution from the Kuskokwim/NE Bristol Bay region.

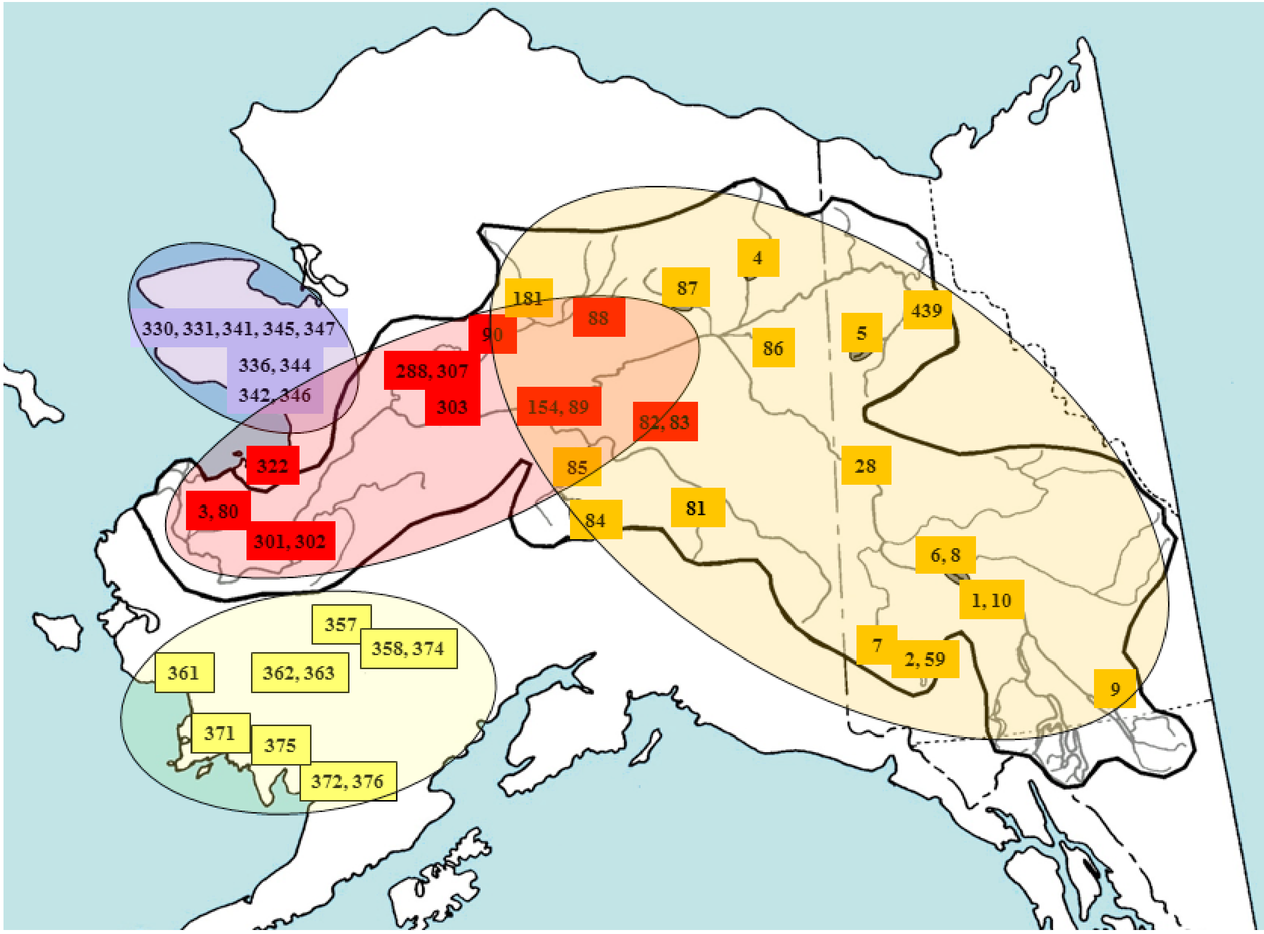


Figure 5. Four finer-scale temporal-spatial population groupings of chum salmon used for mixed-stock analysis: Yukon Summer (red); Yukon Fall (orange); Norton Sound (purple); and Kuskokwim/NE Bristol Bay (yellow). Numbers refer to the population number in the coastwide microsatellite baseline. Base map courtesy of ADF&G.

Table 3. Evaluation of the finer-scale 51-population, 4-temporal-spatial grouping western Alaska/Yukon River chum salmon baseline with simulated mixtures in which 100% of the samples were derived from a single regional grouping (read down columns).

Grouping	Yukon Summer	Yukon Fall	Norton Sound	Kuskokwim/ NEBB
Yukon Summer	**0.846**	0.062	0.073	0.218
Yukon Fall	0.028	**0.923**	0.004	0.005
Norton Sound	0.092	0.006	**0.895**	0.246
Kuskokwim/ NEBB	0.030	0.003	0.023	**0.522**

Stock composition estimates – years pooled

For years 2003 through 2007, samples were aggregated by latitude and longitude to determine the optimal sampling location for estimating proportions of summer- and fall-run Yukon River chum salmon. Samples across years were combined by latitude as follows: 1,244 samples at lat. 58°–59.5°N; 2,736 samples at lat. 60°–63°N; and 296 samples at lat. 63.5°–65°N (Fig. 6). All samples were limited to between long. 166.75° and 172.5°W. First, stock composition estimates were made for all three locations with the 381-population coastwide baseline for six regional groupings (Table 4). Nearly half the fish from the most northern samples were from Coastal Western Alaska with most of the remaining fish from Northeast Asian populations. Two-thirds to three-quarters of the fish from the two locations between lat. 58° and 63°N were from Coastal Western Alaska. Nearly all of the remaining fish were from the Upper/Middle Yukon region.

Second, stock composition estimates were made for the two more southern locations with the finer-scale 51-population western Alaska/Yukon River baseline with four temporal-spatial groupings. Given the large proportion of Northeast Asian fish and the small sample size of the most northern dataset, it was not analyzed with the finer-scale baseline. The contribution of Kuskokwim River fish was low in both areas (Table 4). Because the Yukon Fall fish are identified with high accuracy (Table 3) and because the relative proportion of fall-run fish did not change appreciably between the lat. 58°–59.5°N and 60°–63°N areas, we focused on the samples collected between lat. 58° and 63°N to investigate potential correlations between the relative abundance of fall-run juvenile chum salmon and 1) the parents of the juveniles and 2) the future adult returns of the juveniles.

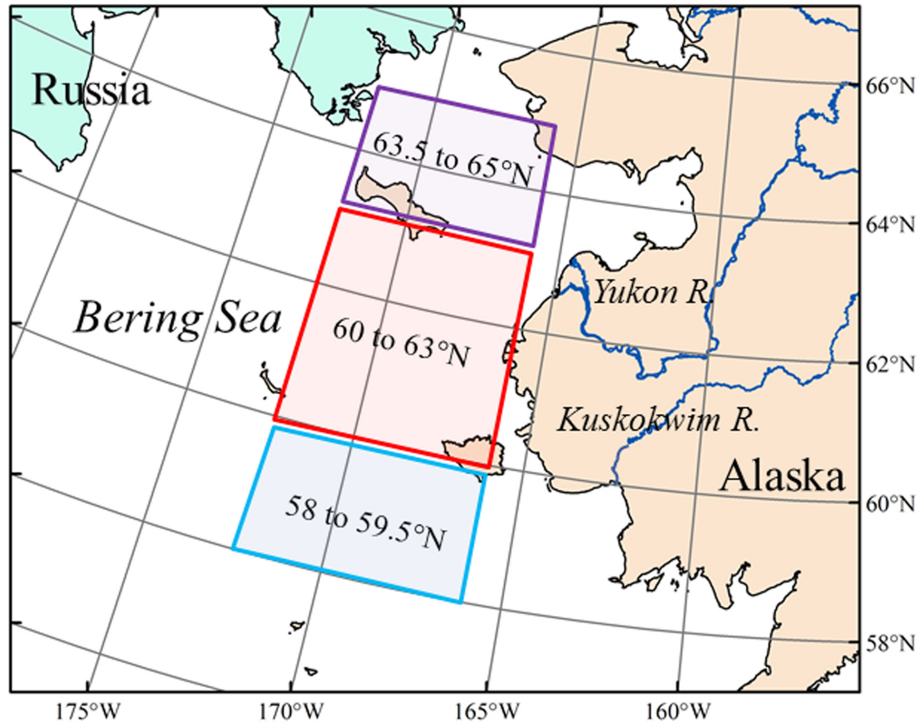


Figure 6. Sampling locations in the Bering Sea. Juvenile chum salmon were collected at stations between approximately lat. 58° and 65°N as part of the annual BASIS cruises in 2003–07.

Table 4. Stock composition estimates of juvenile chum salmon samples collected during 2003–07 for the three spatial areas identified in Figure 6. Estimates with lower credible interval values >0 are identified in bold font. NEBB = northeastern Bristol Bay.

	Spatial areas				
Lat. 63.5-65°N, N=296		Lat. 60-63°N, N=2,736		Lat. 58-59.5°N, N=1,244	
381-population coastwide baseline					
Grouping	Proportion	Grouping	Proportion	Grouping	Proportion
SE Asia	0.001	SE Asia	0.000	SE Asia	0.000
NE Asia	**0.408**	NE Asia	**0.004**	NE Asia	**0.019**
Coast West AK	**0.479**	Coast West AK	**0.752**	Coast West AK	**0.673**
Up/Mid Yukon	**0.111**	Up/Mid Yukon	**0.244**	Up/Mid Yukon	**0.307**
SW Alaska	0.001	SW Alaska	0.000	SW Alaska	0.001
GOA-PNW	0.001	GOA-PNW	0.000	GOA-PNW	0.000
51-population western Alaska/Yukon baseline					
Grouping	Proportion	Grouping	Proportion	Grouping	Proportion
Yukon Summer	—	Yukon Summer	**0.407**	Yukon Summer	**0.444**
Yukon Fall	—	Yukon Fall	**0.205**	Yukon Fall	**0.238**
Norton Sound	—	Norton Sound	**0.311**	Norton Sound	**0.186**
Kuskokwim/NEBB	—	Kuskokwim/NEBB	**0.077**	Kuskokwim/NEBB	**0.132**
Proportion Yukon fall-run relative to total Yukon	n/a		0.34		0.35

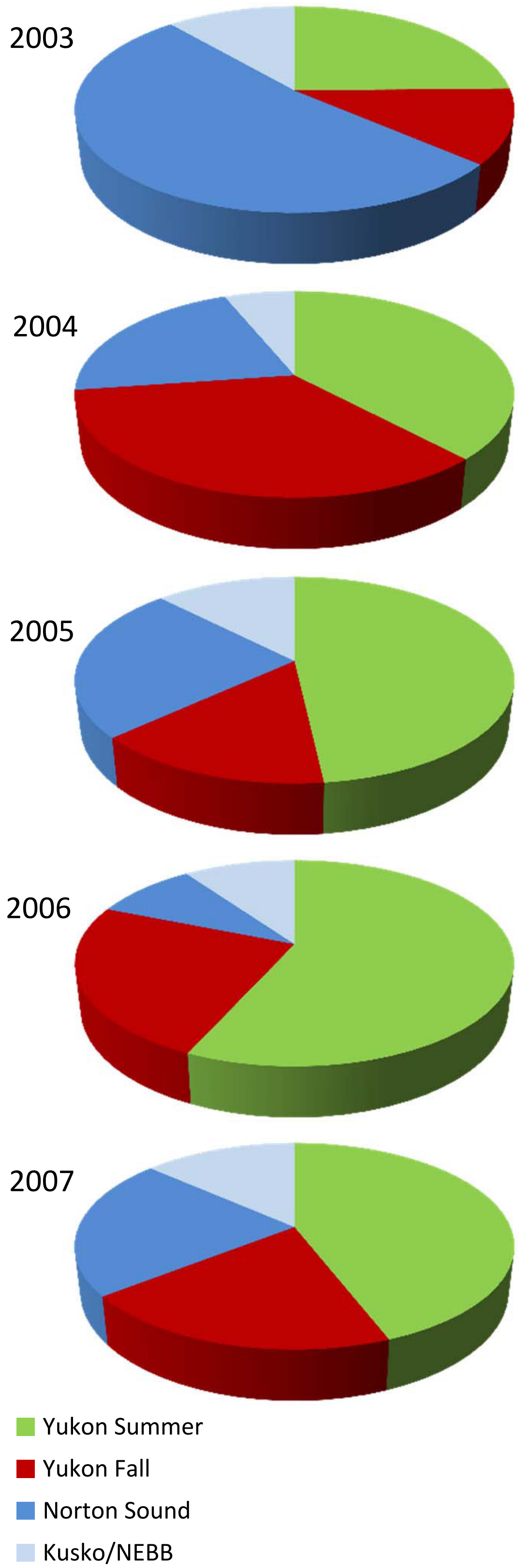


Figure 7. Stock composition estimates for juvenile chum salmon collected during 2003–07 summer/fall BASIS cruises. A 51-population baseline was used to estimate contributions from four western Alaska/Yukon River reporting groups.

The Yukon Summer contribution was always higher than the Yukon Fall contribution.

Stock composition estimates – western Alaska/Yukon groupings

With the 51-population western Alaska/Yukon River chum salmon baseline comprised of four temporal-spatial groupings, stock composition estimates were made for each year for samples collected between lat. 58° and 63°N (Fig. 7). Except in 2003 when approximately 50% of the juvenile chum salmon collected on the eastern Bering Sea shelf were from Norton Sound populations, most of the juvenile chum salmon originated from the Yukon Summer populations. The Yukon Summer contribution was always higher than the Yukon Fall contribution. Typically about 10% of the juvenile chum salmon samples originated from the Kuskokwim River/northeastern Bristol Bay populations.

Yukon River chum salmon: abundance estimates and correlation of juvenile and adult fall-run proportions

Across years, the proportion of fall-run adult returns of Yukon River chum salmon based on the ADF&G abundance estimates varied inter-annually (Fig. 8). On average, 32% of the annual return between 2000 and 2012 was classified as a fall stock, with a high of 47% in 2005 and a low of 22% in 2006. A large return of age-3 and age-4 fish sometimes corresponded to a large return of age-4 and age-5 fish, respectively, the following year (Fig. 9).

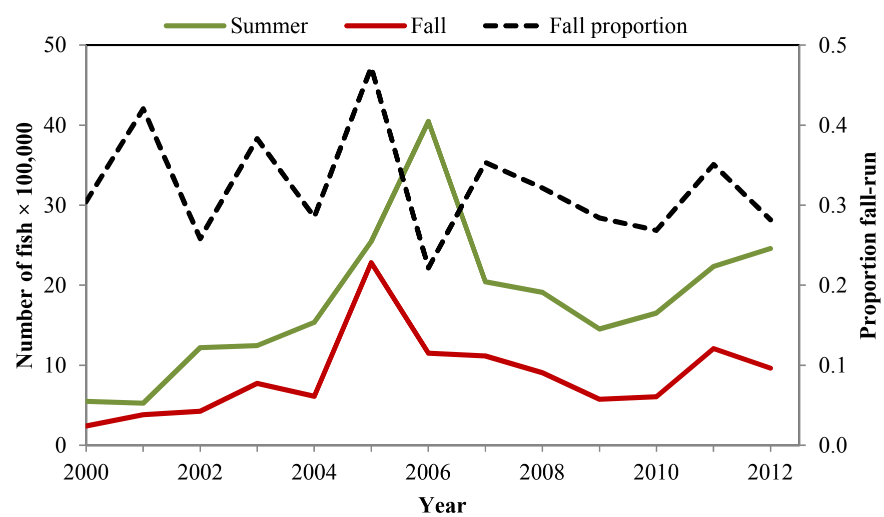


Figure 8. Annual summer- and fall-run adult returns of chum salmon to the Yukon River drainage. Estimates of return are on the left y-axis and proportions of fall-run chum salmon are on the right y-axis.

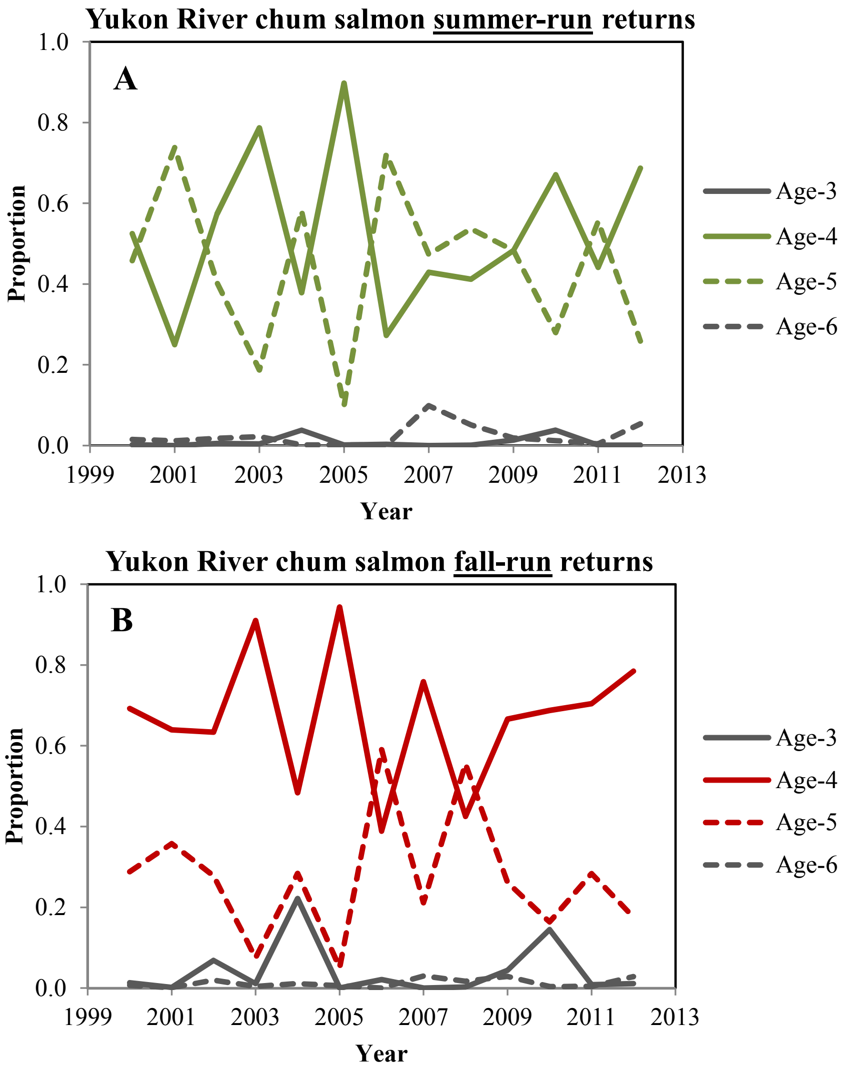


Figure 9. Proportion of age-3 to age-6 chum salmon adult returns to the Yukon River for A) summer-run fish, and B) fall-run fish.

To determine the proportion of fall-run adults that produced the juveniles collected in 2003–07, the abundance estimate for the fall-run from the year previous to each year of juvenile sampling was divided by the total Yukon River return (summer + fall). For example, the 2003 juveniles sampled at sea were spawned by the 2002 adult returns (Table 5). To determine the proportion of each juvenile year-class that returned as fall-run adults across four years, the abundance estimates that tracked ages 3–6 were summed for each run component and then the fall-run abundance was divided by the total return (summer + fall). For example, some of the 2003 juveniles would have returned as age-3 adults in 2005, as age-4 in 2006, as age-5 in 2007, and finally as age-6 in 2008 (see Table 5). A correlation was found between the proportions of fall-run juveniles estimated from genetic analysis and the adult brood-year returns calculated from abundance estimates. This relationship was further supported by data for the 2002 sample year that was produced from an earlier study with allozyme markers (Fig. 10). There was no correlation between the proportion of fall-run juveniles and the parents that produced those juveniles.

A correlation was found between the proportions of fall-run juveniles estimated from genetic analysis and the adult brood-year returns calculated from abundance estimates. This relationship was further supported by data for the 2002 sample year that was produced from an earlier study with allozyme markers

Processing juvenile salmon catch. EMA Program

Table 5. Matrix of juvenile collections and adult returns of Yukon River chum salmon. The blue cells identify the juveniles collected at sea. The yellow cells identify the parent year of the juveniles. The orange cells identify the age of the adult brood-year returns in relation to year of juvenile collections.

		Adults										
		2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Juveniles	2003		Age-1	Age-2	Age-3	Age-4	Age-5	Age-6				
	2004			Age-1	Age-2	Age-3	Age-4	Age-5	Age-6			
	2005				Age-1	Age-2	Age-3	Age-4	Age-5	Age-6		
	2006					Age-1	Age-2	Age-3	Age-4	Age-5	Age-6	
	2007						Age-1	Age-2	Age-3	Age-4	Age-5	Age-6

Eastern Bering Sea, August 2011.
Chris Kondzela

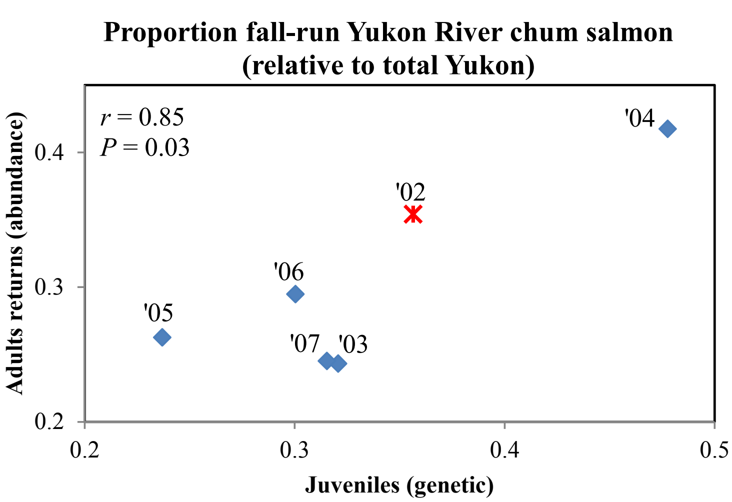


Figure 10. The yearly relative proportion of fall-run Yukon River juvenile chum salmon collected in the eastern Bering Sea between lat. 58° and 63°N during 2003–07, versus the brood-year adult returns. Microsatellite marker data indicated with blue diamonds and allozyme marker data with a red star.

Summary

The availability of multi-year collections of juvenile chum salmon from the eastern Bering Sea and the comprehensive genetic information of chum salmon populations throughout their geographic distribution provided an opportunity to examine the distribution of western Alaskan chum salmon during their first summer/fall at sea. For the first time that we are aware of, our study investigated the relationship of the stock compositions of juvenile chum salmon collected at sea and the Yukon River adult chum salmon returns. Because the genetic diversity of coastal western Alaska chum salmon populations (summer-run) is low and therefore challenging to apply to mixed-stock analyses, we focused on the Yukon River, which has fall-run populations that are genetically distinct from the summer-run populations. Estimates of the proportions of the two life-history types in mixtures of juveniles were used to examine year-to-year differences in distributions in the Bering Sea during early marine residence, and to investigate the potential association of juvenile abundances with Yukon River adult returns.

The estimated stock proportions of juvenile chum salmon caught in the eastern Bering Sea during late summer/fall over a 5-year time period adds to our understanding of the distribution of western Alaska chum salmon during their first year in the ocean. Our results support a migration model whereby western Alaska juvenile chum salmon head primarily west and south across the eastern Bering Sea shelf during the summer/fall season. With both the full coastwide baseline and the finer-scale western Alaska baseline, the contributions from each stock grouping of this highly migratory species were remarkably similar from year-to-year, especially given the inter-annual latitudinal shifts in juvenile chum salmon distribution across the eastern Bering Sea shelf (Fig. 1), as well as the variation in the date that stations were sampled across years. Nearly all of the juvenile chum salmon were from the Coastal Western Alaska and Upper/Middle Yukon River stock groupings (Fig. 3), as was found in an earlier genetic analysis of samples from 2002. Except in 2003, the highest proportion of juvenile chum salmon caught in the surveys was from the Yukon Summer populations. In all years, the Yukon Summer component was higher than the Yukon Fall component. The contribution from Norton Sound varied annually, but in general, increased with latitude (Table 4). Given the low abundance of many Norton Sound chum salmon populations in some years, surveys in the northeastern Bering Sea might help provide insight into the early marine residence of these populations. Previous analyses indicated that samples collected below lat. 60°N contained Kuskokwim origin fish, although our analysis suggests that Kuskokwim/NE Bristol Bay origin fish were only a minor component as far south as lat. 58°N and did not migrate northward during their first summer. This difference may simply reflect inter-annual variation of migration routes or an effect of sampling west of long. 166.75°W, an area potentially outside the migration route of the Kuskokwim origin chum salmon during the 2003–07 surveys.

On average, across the 5-year dataset, about one-third of the Yukon River juvenile chum salmon were from fall-run populations based on genetic stock estimates, much like the adult returns based on abundance estimates. Although no correlation was found between the estimated proportion of fall-run Yukon River juvenile chum salmon in the sample sets and the adult year-classes that produced them, a significant correlation was found between the juveniles and the brood-year returns. In 2004, the departure of the relative survival of the two life-history types in the Yukon River provided contrast in the correlation analysis of the proportions of fall-run juveniles and brood-year returns. The significant correlation suggests that differences in the production and survival of the summer- and fall-run populations occur during the period of freshwater and early marine residence.

For the first time that we are aware of, our study investigated the relationship of the stock compositions of juvenile chum salmon collected at sea and the Yukon River adult chum salmon returns.

In most years, the abundance of fall-run fish is usually well-correlated with the abundance of summer-run fish (Fig. 8), but infrequently, the fall-run proportion is substantially higher or lower than expected, e.g., higher in 2005. The relative proportions of fall-run juvenile chum salmon provide insight into the relative strength of fall-run adult returns. For example, juvenile chum salmon produced from the 2001 and 2002 year-classes have different impacts on the 2005 adult returns. There were few age-3 fall-run Yukon River chum salmon returns in 2005, so the juveniles produced from the 2002 year-class did not contribute significantly to the 2005 adult returns. However, 94% of the fall-run component in 2005 was comprised of age-4 fish (Fig. 9) that were produced from the 2001 year-class of juveniles (sampled in 2002), which from our earlier study based on a different set of genetic markers had a relatively high proportion of fall-run fish (Fig. 10).

The proportion of fall-run juveniles that return as adults is spread across multiple years due to the age structure of chum salmon. Thus, the high proportion of fall-run juveniles from the 2003 year-class (collected in 2004) contributed to adult returns in 2006 as age-3, in 2007 as age-4, in 2008 as age-5, and in 2009 as age-6. The age-3 and age-6 contributions were only 2%-3% of the fall-run return in 2006 and 2009, but the high proportion of fall-run juveniles caught in 2004 is evident as age-4 fish, which comprised 76% of the 2007 fall-run return, and as age-5 fish, which comprised 56% of the 2008 fall-run return (Fig. 9), the second highest proportion of age-5 fall-run returns in years 2000–12.

Conclusions

The results of our study indicate that by the time juvenile chum salmon are caught on the continental shelf of the eastern Bering Sea in late summer/early fall, the relative proportion of summer and fall fish appears to have been determined for that brood year.

The juvenile fall-run proportions may be useful in managing the Yukon River fall-run stock group. Chum salmon are currently managed with the assumption of a constant ratio of fall and summer abundance. The stock proportions of juveniles could improve this strategy by forecasting the relative strength of fall and summer runs to the Yukon River.

Future investigations should incorporate ongoing advances in the genetic baselines, which may improve the accuracy of the stock composition estimates in the western Alaska region, particularly for the summer coastal stocks. Analyses of samples collected during more recent years (2009–12) may further clarify the relationship between the juvenile and adult chum salmon from the Yukon River.

Acknowledgements

We are grateful to Emily Fergusson for coordinating sample processing, to Wei Cheng and Hanhvan Nguyen for the DNA extraction of many of the juvenile chum salmon samples, to Colby Marvin for laboratory analyses, and to Jackie Whittle for exploratory data analyses. Yukon River chum salmon adult abundance estimates were provided by Katie Howard from ADF&G. Discussions with Katie and Bill Templin from ADF&G are greatly appreciated. Funding was provided by Alaska Sustainable Salmon Fund (Project 44619) and the Arctic-Yukon-Kuskokwim Sustainable Salmon Initiative (Project 1002/SAF-336).