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JOSHUA GREEN RIVER PACIFIC SALMON STOCK ASSESSMENT AND RESIDENT FISH SPECIES SURVEY, IZEMBEK NATIONAL WILDLIFE REFUGE, ALASKA 1994 - 1996

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Abstract. −In 1994-1996, four species of Pacific salmon, and Dolly Varden char *Salvalinus malma* were captured in the Joshua Green River on the Izembek National Wildlife Refuge. Chum salmon *Oncorhynchus keta*, were first captured in late June all 3 years, but a bimodal capture distribution indicated an early and late run. The early run preferred the right fork, while the late run used primarily the left fork. Sockeye *O. nerka* and pink salmon *O. gorbuscha* used primarily the right fork, and although coho salmon *O. kisutch* used both forks, capture rates also indicated a strong preference for the right fork. The early chum salmon run peaked in mid-July while the late run peaked in early September. Sockeye salmon peaked in mid-July, while pink salmon peaked in the first half of August, and coho salmon appeared to peak during the second half of September. Sex composition was variable among species. During all 3 years, the percent of female chum, coho, and pink salmon captured in most locations generally increased throughout the season while the percent of female sockeye salmon was variable throughout the run. Salmon mid-eye-to-fork length and age composition were also variable, but differences occurred between locations for all species. Dolly Varden char (char) used both the right and left fork, but smaller (190-330mm) char were more common in the right fork. Analysis of Dolly Varden char otoliths indicated there were seven different age classes (3 to 9) sampled in 1995 and1996.

Introduction

The Joshua Green River, located in the northern portion of the Izembek National Wildlife Refuge, is the largest river drainage on the refuge. The river, fed by numerous mountain headwater streams and lowland springs, empties into Moffet Bay of Izembek Lagoon. Although there is virtually no subsistence fishing and only limited sport fishing on the river itself, Moffet Bay and the surrounding coastal waters are subject to commercial fishing for Pacific salmon (A. Shaul, Alaska Department of Fish and Game, personal communication). The Joshua Green River drainage is an important feeding

area for large populations of brown bears *Ursus arctos* and bald eagles *Haliaeeteus leucocephalus* which depend heavily on Pacific salmon for food (U.S. Fish and Wildlife Service 1985). Additionally, Pacific salmon play a key role in providing annual nutrient enrichment to the riverine and estuarine ecosystems, which are critical to thousands of migrating waterfowl, shorebirds, coastal fishes, and marine mammals (U. S. Fish and Wildlife Service 1994).

Management of the Joshua Green River, by the Alaska Department of Fish and Game Commercial Fisheries Management and Development Division, is based on aerial escapement surveys and commercial catch per unit effort data (Alaska Department of Fish and Game 1993). Aerial surveys which focus on chum *Oncorhynchus keta*, sockeye *O. nerka*, and pink salmon *O. gorbuscha,* are conducted several times each summer to estimate Pacific salmon escapement. Adult aerial escapement estimates in the Joshua Green River have averaged about 137,600 chum and 15,300 sockeye salmon over the last 10 years. Escapement counts of pink salmon have been erratic, varying from 200 in 1984 and 1986 to 21,800 in 1990. Escapement for chinook salmon has been less than 100 fish in any year since 1974, following a 30 year high of 6,900 fish in 1969 (Alaska Department of Fish and Game 1993). No aerial surveys have been conducted for coho salmon escapement and little information on the coho salmon population exists other than reports of incidental catches in the commercial fishery.

The primary concern of the refuge manager is that escapement goals are being met to insure an adequate number of Pacific salmon are available for maintaining the critical riverine and estuarine ecosystems of the Joshua Green River drainage. Current management in the Joshua Green River drainage is directed towards chum and sockeye salmon, and without ground truthing of aerial escapement surveys, inaccurate escapement estimates may lead to over harvest of fish stocks. This could have long term negative impacts on Pacific salmon populations and other wildlife species that are directly and indirectly dependent upon them.

Currently, there are little data concerning resident species in the Joshua Green River drainage. Though these species contribute little to commercial, subsistence, or sport fisheries, they have a role in the functions of the Joshua Green River ecosystem. Proper management of the drainage must be based on knowledge of these functions and abundance of all species. Adams et al. (1993) recommended that further studies be conducted to complement their survey of several lakes and streams on the Izembek Refuge (including Paul Hansen Lake and the Joshua Green River). Lakes and streams were sampled with experimental gill nets, electrofishing, minnow traps, dipnets, and angling. Effective sampling was not possible on the Joshua Green River because of electofisher failure. Although their study was limited by logistics, and complete information on all species in all water bodies was not possible, it served as a baseline for future studies. In 1994 the King Salmon Fishery Resource Office initiated a 3 year study to collect and evaluate additional data from the Joshua Green River drainage. The objectives of the study were to (1) determine run timing and sex, age, and length compositions for adult Pacific salmon, and (2) determine run timing and age and length compositions for adult Dolly Varden char found in the drainage.

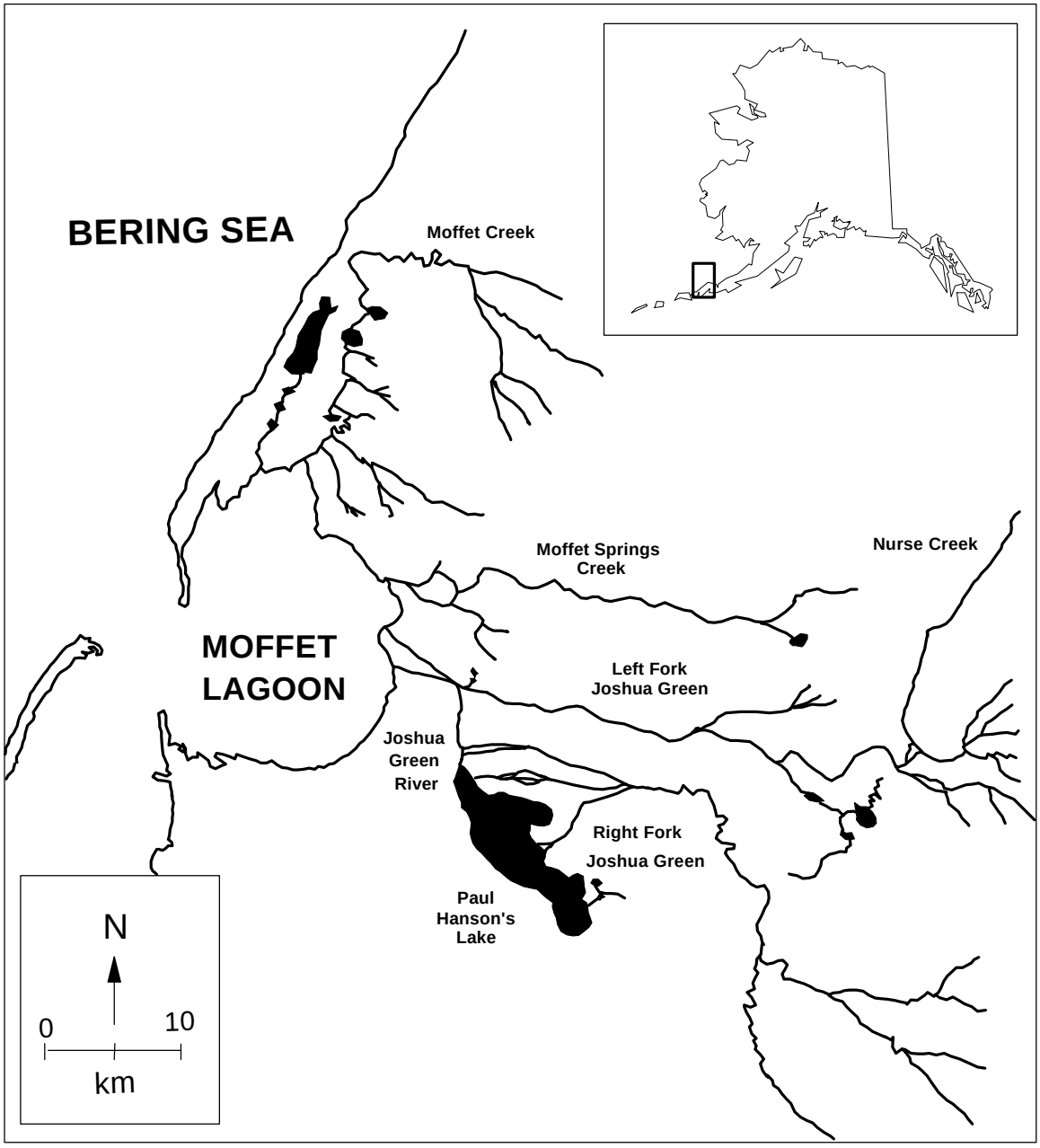

Figure 1. Map of the Joshua Green River on the Izembek National Wildlife Refuge.

Study Area

The Joshua Green River has two major forks which join about 2 km upstream of Moffet Bay (Figure 1). Both forks are intersected by numerous tributaries which drain glaciers and high mountains of the southern tip of the Aleutian Range. Numerous springs join the river in its lower reaches. The tributaries range in width from 0.2-5.0 m, and depth from 0.1-1.5 m. Substrates of the tributaries are predominately gravel with sand present only in pools. The tributaries and springs appear

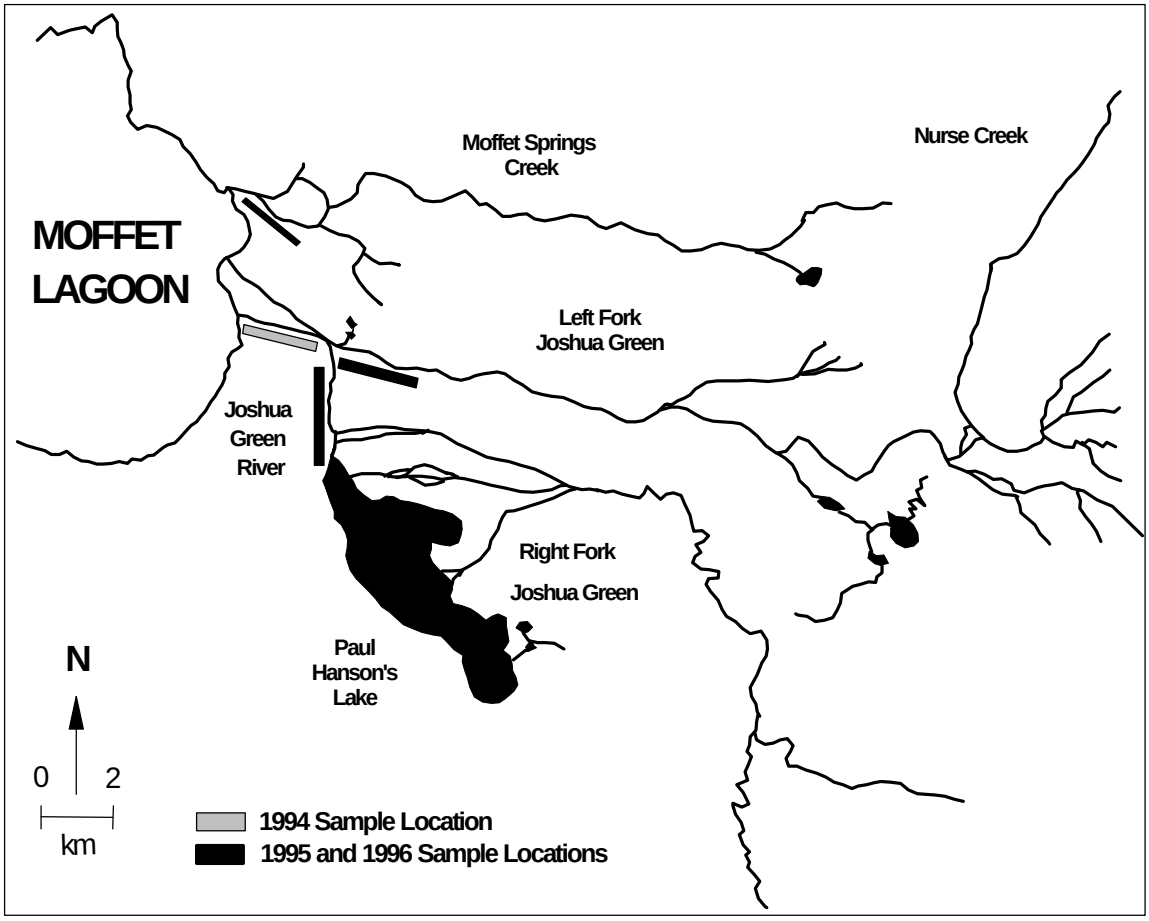

Figure 2. Sample locations in the Joshua Green River drainage, 1994-1996.

to provide the majority of available spawning habitat within the drainage. The lower reaches of both forks are wide (70-80 m), well defined incised (1-3 m) channels flowing through a semi-bog flood plain. Substrate is loose sand, which results in continuously changing pool, run, and sand bar locations. The mainstems are generally turbid due to glacial sediments and runoff from frequent rain while the tributaries remain clear except for brief periods after heavy rains. Paul Hansen Lake (192 ha) which is also turbid, is located on the right fork, while several small clear tundra lakes (generally < 0.2 ha) are connected to the left fork.

In addition to the five species of Pacific salmon, other species known to exist in the drainage include coast range sculpin *Cottus aleuticus*, threespine sticklebacks *Gasterosteus aculeatus*, ninespine sticklebacks *Pungitius pungitius*, and Dolly Varden char *Salvelinus malma* (U.S. Fish and Wildlife Service 1993).

Methods

Run Timing

Adult Pacific salmon and Dolly Varden char were sampled in the Joshua Green River during 1994-1996 and in Moffet Springs Creek in 1996. In 1994 (July 1-September

12), sampling was conducted in the mainstem below the confluence of the right and left forks (Figure 2). The 1994 results indicated an early and late run of chum salmon, and that the right and left forks were not used equally by all salmon species. Therefore, to describe each fork, sampling was modified and sample locations in 1995 (June 20 - September 23) and 1996 (June 25-October 4) were located as low as possible on each fork. The sample area on the right fork was a 1.6 km section of the river immediately below Paul Hansen Lake, and the sample area on the left fork was a 1.6 km section of the river immediately upstream of the confluence with the right fork (Figure 2). Samples from each fork were treated independently. The sample location in Moffet Springs Creek was the lower 1.6 km of the mainstem (Figure 2).

A beach seine (45.7 m x 1.8 m x 3.8 cm mesh) was the primary method for capturing salmon and Dolly Varden char in the Joshua Green River, and a 9.1 m x 1.2 m bag seine with 2.5 cm bar mesh was used for the same species in Moffet Springs Creek. In 1994, salmon and Dolly Varden char were sampled 4 days each week, while in 1995 and 1996 fish were sampled once per week in each fork. In 1996, fish were sampled in Moffet Springs Creek one day each week.

Length, Sex, and Age Data

General.—Length was recorded for all adult salmon and Dolly Varden char captured in the seine hauls when the number captured was small enough to prevent stress from overcrowding (approximately 250/haul). Sex was also recorded for all salmon species. If more than 250 fish were captured in a seine haul, excess fish were counted out by species to prevent stressing fish retained for sampling. To prevent resampling, the adipose fin was clipped on all species.

Pacific Salmon.—Length of Pacific salmon was measured from mid-eye to fork-of-caudal fin (MEF, mm), and sex was determined by secondary sex characteristics. To estimate age compositions for chum, sockeye, and coho salmon, scales were collected from the preferred area on the fish (Jearld 1983). Using the 1993 indexed annual escapements for chum and sockeye salmon (104,000 chum and 17,000 sockeye) (A. Shaul, Alaska Department of Fish and Game, personal communication) and calculations from Schlesselman (1982), minimum seasonal sample sizes of 383 chum and 376 sockeye salmon were necessary for age analysis. Assuming that not all scale samples would be readable, a minimum of 400 scale samples was targeted from both species. Annual estimates for coho salmon escapement ranged from 500-1,500 fish (A. Shaul, Alaska Department of Fish and Game, personal communication); therefore, a minimum sample size of 300 fish was necessary for age analysis. The predetermined sample sizes were the targeted minimum seasonal sample sizes for 1994 and 1995. However in 1996, the minimum seasonal sample size for coho salmon was increased to 400 because catch rates in 1994 and 1995 were higher than expected. In 1995 and 1996, minimum seasonal sample sizes for each species were applied to each fork independently. Based on 1994 run timing and capture data, a fixed number of scale samples were collected each week (40 chum and 80 sockeye and coho salmon) in 1995 and 1996. When salmon numbers were low, every chum, sockeye, and coho salmon was sampled for scales, but as capture rates increased, the sampling proportion was decreased to every second,

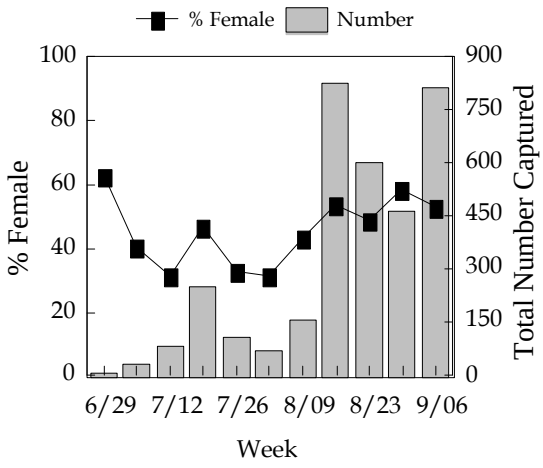

Figure 3. Chum salmon run timing (total number captured) and sex composition (%female) in the mainstem of the Joshua Green River, 1994.

third, fourth, sixth or eighth fish of each species. In 1994, additional sampling was conducted on the right fork just below Paul Hansen Lake to obtain the necessary sample size for age analysis of sockeye salmon. However, these fish were not used to determine sockeye salmon run timing. Scales were aged independently by two people and disagreements resolved by conference. Age designations are expressed in the European fashion (Koo 1962) where numerals preceding the decimal denote winters spent in freshwater, and numerals following the decimal designate winters spent in saltwater.

Dolly Varden Char.**S**The lengths of Dolly Varden char were measured from tip-of-snout to fork-of-caudal fin (FL, mm). In 1995, all Dolly Varden char retained for sampling were measured, and a subsample of char >250 mm were marked with anchor tags (Floy Tag and Manufacturing, Seattle WA) to determine movements within the Joshua Green River during the summer. The upper reaches of both forks were sampled approximately once a week to recapture marked Dolly Varden char. To determine the age range of Dolly Varden char, otoliths were collected in August-September from 2-3 char in each 10 mm length class from 200 to 650 mm. In 1996, Dolly Varden char captured in the left and right forks were tagged as in 1995. However, the minimum length for tagging was 300 mm, and fish that appeared sick or injured were not tagged. No additional sampling was conducted in the upper reaches of both forks. Otolith samples were collected in July and August from both forks.

Data Analysis

Two-sample t-tests ($\alpha = 0.05$) were used to compare the mean MEF of Pacific Salmon and FL of Dolly Varden char between sample locations. Comparisons were not made if sample sizes were < 30 fish.

Results

Chum Salmon

Run Timing and Sex Composition.**S**In 1994, chum salmon began entering the Joshua Green River in late June. Weekly catch rates peaked in mid-July (N = 225), declined for the next 3 weeks and then increased to a second peak in mid-August (N = 825; Figure 3). The bimodal capture distribution for 1994 indicated the possibility of an early and late run of chum salmon in the Joshua Green River. In 1995 and 1996, chum salmon entered the right fork in late June, peaked in late August, and had declined by early to mid-September (Figure 4 and 5). Less than four chum salmon were captured in the left fork before late July either year. The run in the left fork peaked in early September and quickly declined by late September both years. Moffet Springs

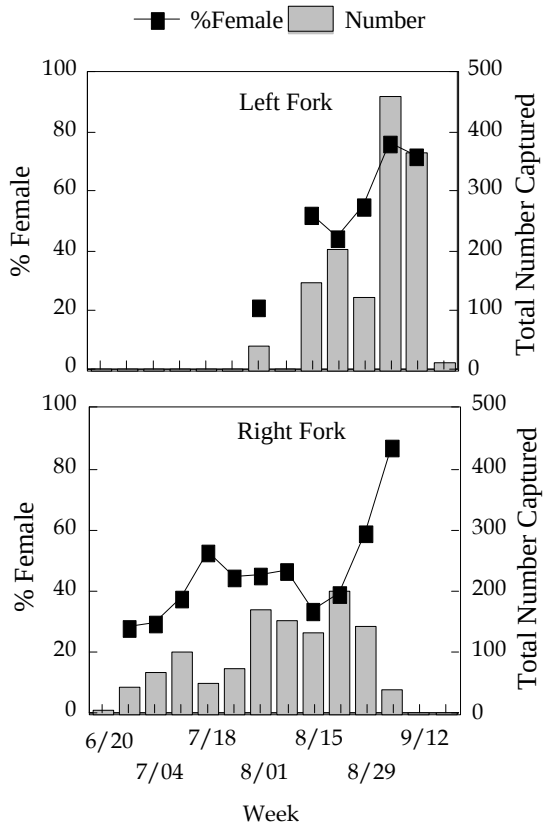

Figure 4. Chum salmon run timing (total number captured) and sex composition (% female) in the right and left forks of the Joshua Green River, 1995.

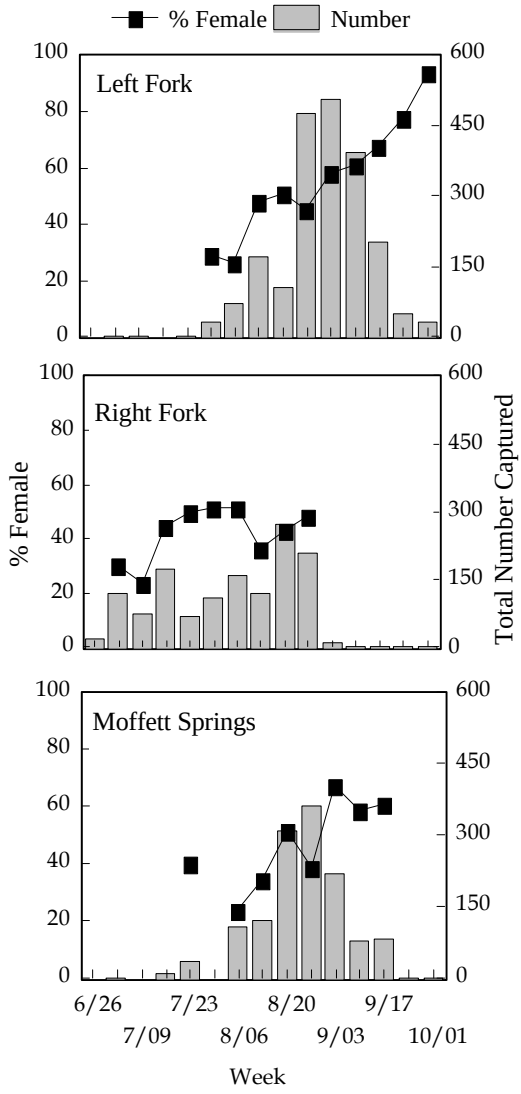

Figure 5. Chum salmon run timing (total number captured) and sex composition (% female) for three locations in the Joshua Green drainage, 1996.

Creek was only sampled in 1996, but the run peaked in late August and declined rapidly in late September (Figure 5).

Chum salmon sex composition in the Joshua Green River exhibited no clear patterns in 1994. The percent of females (% female), defined as the percent of females in the total weekly catch, varied between 31.3 - 58.4% during the run (Figure 3). As the early run weekly catch declined, so did the percent of females, but as numbers increased during the late run, the percent of females also increased from 31.4% to 58.4% (Figure 3). In 1995 and 1996, the percent of females captured in the left fork generally increased throughout the run in the left fork (Figure 4 and 5). However, the run in the right fork did not show an obvious pattern of increase, and actually decreased the third week of August both years (Figure 4 and 5). As with run timing, the 1996 seasonal patterns of sex composition in Moffet Springs Creek were similar to those in the left fork of the Joshua

Table 1. Chum salmon mean mid-eye to fork lengths (mm), standard deviations (SD), and ranges in the Joshua Green River Drainage, 1994-1996.

	Males				Females			
Location	N	Mean	SD	Range	N	Mean	SD	Range
				1994				
Mainstem	1,572	583.0	43.8	422-720	1,594	571.2	32.6	462-695
Right Fork	170	599.5	40.3	420-713	93	579.5	31.7	517-655
				1995				
Left Fork	293	583.9	46.3	435-848	427	574.3	30.2	468-654
Right Fork	630	598.7	32.8	490-688	490	574.9	28.8	491-622
				1996				
Left Fork	502	595.4	49.6	423-742	636	581.5	35.1	442-689
Right Fork	619	624.2	36.9	461-726	462	590.2	34.1	419-677
Moffet	453	611.2	43.4	448-731	417	585.1	37.2	455-701

Green River (Figure 5). The percent of females in weekly catches increased from 23.8% in early August to highs in September ranging from 59.0-67.5%. The percent of females for those weeks where the total catch was < 30 fish were not included in comparisons (Figure 3-5).

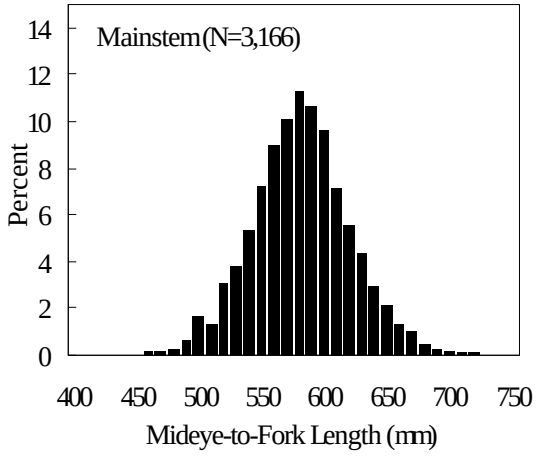

Figure 6. Length frequency for chum salmon captured in the mainstem of the Joshua Green River, 1994.

Length and Age Distributions.**S**In 1994, no comparison of mean MEF was made between the mainstem and the right fork because the right fork was only sampled 4 weeks (Table 1 and Figure 6). In 1995, male chum salmon captured in the right fork were larger than males captured in the left fork (t = 5.543, $P < 0.001$), but the mean MEF of females was not different between forks (t = 0.351, P = 0.726; Table 1 and Figure 7). In 1996, male chum salmon captured in the left fork were smaller than those captured in the right fork (t = 10.773, $P < 0.001$) and Moffet Springs Creek (t = 5.244, $P < 0.001$; Table 1 and Figure 8). Males captured in Moffet Springs Creek were smaller than those captured in the right fork (t = 5.127, $P < 0.001$). Female chum salmon captured in the right fork in 1996 were larger than those captured in the left fork (t = 4.190, $P < 0.001$) and Moffet Springs Creek (t = 2.176, P = 0.030), but females captured in the left

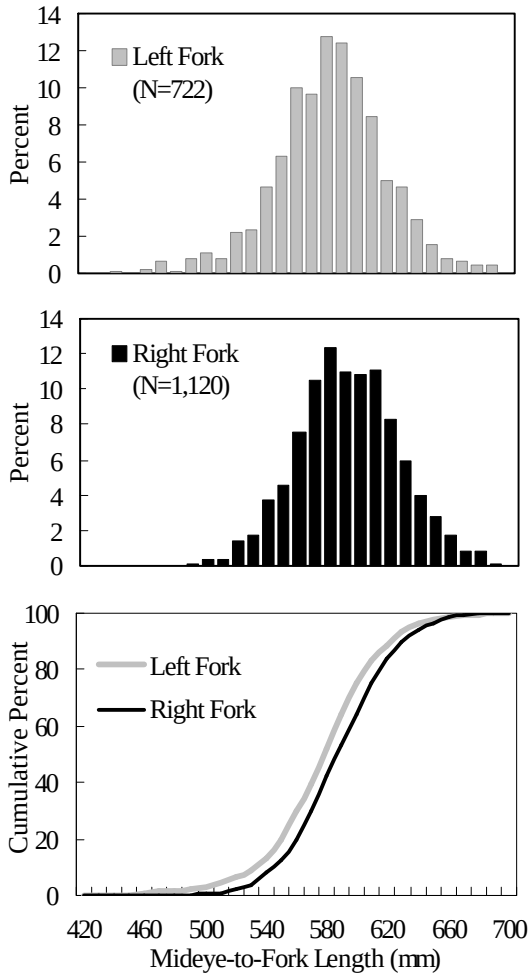

Figure 7. Length frequency and cumulative length frequency for chum salmon captured in the left and right forks of the Joshua Green River, 1995

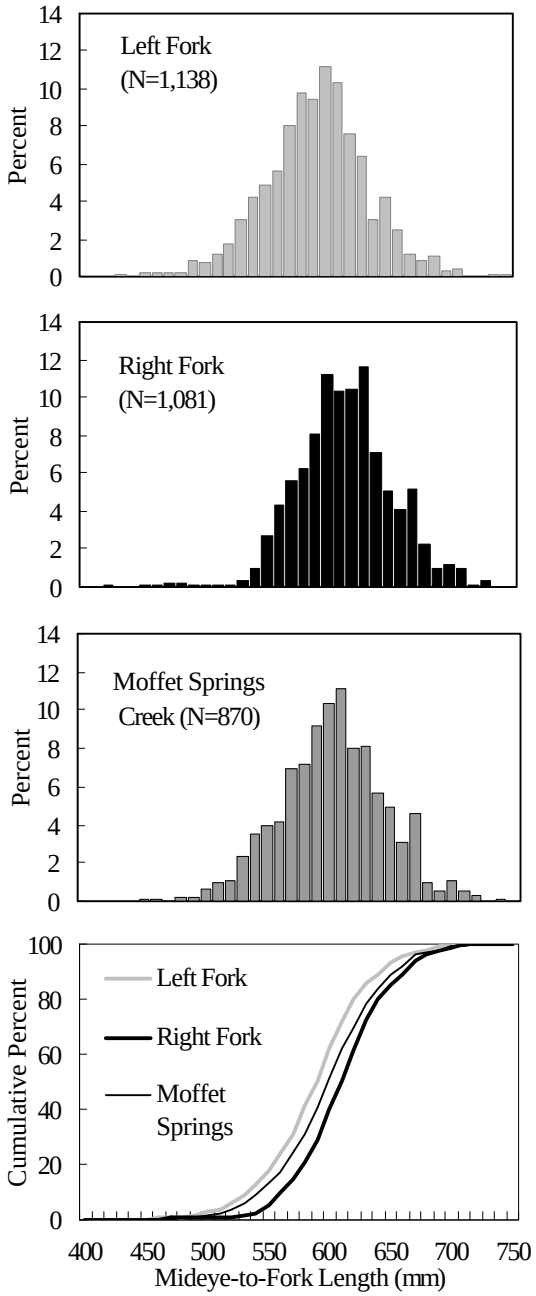

Figure 8. Length frequency and cumulative length frequency for chum salmon captured in three locations in the Joshua Green River drainage, 1996.

fork and Moffet Springs Creek were not different (t = 1.580, P = 0.114; Table 1 and Figure 8.)

Age distributions of chum salmon were fairly similar between sexes in all 3 years and most locations (Table 2). The modal age was 0.3 years for both sexes and all locations other than the right fork in 1994 where the modal age was 0.4 years. However, age distributions for 1994 may not accurately describe the right fork run because fish were only sampled 4 weeks.

Table 2. Male and female chum salmon age composition (%) and sample sizes (N) for several locations in the Joshua Green River Drainage, 1994-1996.

	1994		1995		1996		
Age and Sex	Right Fork	Mainstem	Right Fork	Left Fork	Right Fork	Left Fork	Moffet Springs
0.2							
Male	8.8	9.5	8.5	15.5	4.3	11.3	6.1
Female	0.0	6.9	7.1	5.5	0.0	7.3	4.6
0.3							
Male	32.4	44.6	54.0	71.1	63.7	70.2	60.0
Female	37.5	44.1	62.3	82.7	73.1	68.4	59.5
0.4							
Male	52.9	42.4	27.5	11.3	21.8	12.6	27.3
Female	56.3	45.8	19.7	10.2	20.6	19.2	27.5
0.5							
Male	5.9	3.2	10.1	1.0	2.6	0.7	0.6
Female	6.3	2.6	10.9	1.6	0.7	2.6	2.0
1.3							
Male	0.0	0.3	0.0	1.0	0.0	0.0	0.0
Female	0.0	0.3	0.0	0.0	0.0	0.0	0.0
1.4							
Male	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Female	0.0	0.3	0.0	0.0	0.0	0.0	0.0
2.2							
Male	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Female	0.0	0.0	0.0	0.0	0.7	0.0	0.0
Unknown							
Male	---	---	---	---	7.7	5.3	6.1
Female	---	---	---	---	4.8	2.6	6.5
N							
Male	34	316	189	97	234	151	165
Female	16	306	183	127	145	193	153

Sockeye Salmon

Run Timing and Sex Composition. In 1994, sockeye salmon were captured in the mainstem of the Joshua Green River the first week of sampling (June 28-July 4), and the weekly catch peaked the third week of July (N = 76; Figure 9). Sockeye salmon were also captured in the right fork, but were not used to determine run timing. In 1995 sockeye salmon were first captured in the right fork late June, and the weekly catch peaked the third week of July (N = 1,099; Figure 10). Run timing in 1996 was similar to 1995, as sockeye salmon were first captured the last week of June, and weekly catch rates peaked the third week of July (N

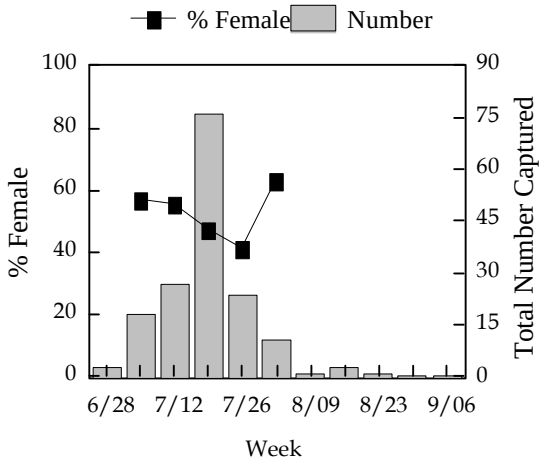

Figure 9. Sockeye salmon weekly run timing (total number captured) and sex composition (% female) in the mainstem of the Joshua Green River, 1994.

= 346; Figure 11). Sockeye salmon used primarily the right fork as only seven sockeye salmon were captured in the left fork in 1995 and 21 in 1996. Run timing in Moffet Springs Creek, appeared to peak later during the first week of August (N =

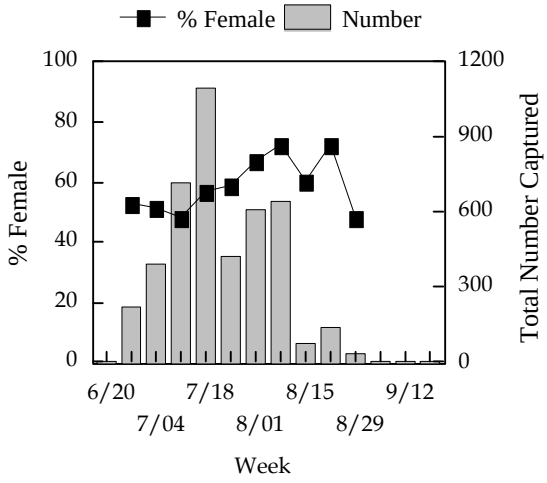

Figure 10. Sockeye salmon weekly run timing (total number captured) and sex composition (% female in the right fork of the Joshua Green River, 1995.

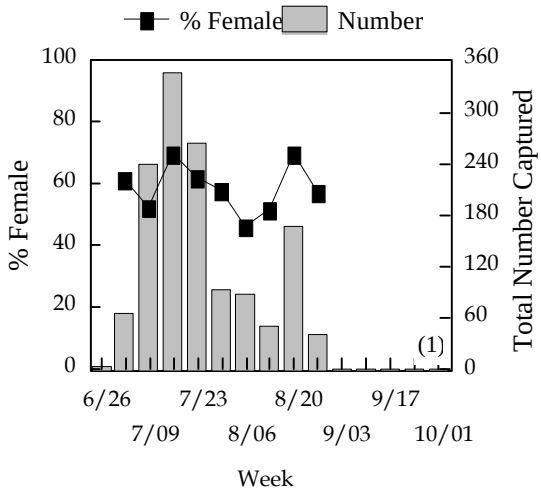

Figure 11. Sockeye salmon weekly run timing (total number captured) and sex composition (% female) for the right fork of the Joshua Green River, 1996.

34), but the creek was not sampled the last week of July, and the total catch for the summer was only 83 fish.

Sockeye salmon sex composition was less variable and patterns less distinct than chum salmon. In 1994, the percent of female sockeye salmon captured weekly varied between 41.7% and 63.6% in the mainstem, but catch rates were often <30 fish (Figure 9). Females were 49.0% of the mainstem sample for the entire season. In 1995, the percent of females captured in the right fork initially declined from 53.0% the last week of June to 48.0% the second week of July, but then increased the next 4 weeks to 72.9% (Figure 10). Females were 57.9% of the right fork sample for the entire season. In 1996, the percent of females captured in the right fork varied from a low of 46.3% to a high of 70.1% the third week of August, but the percent of females captured for the season was 61.1% (Figure 11). No distinct patterns were seen in the left fork and Moffet Springs Creek sockeye salmon runs.

Table 3. Sockeye salmon mean mid-eye to fork lengths (mm), standard deviations (SD), and ranges in the Joshua Green River Drainage, 1994-1996.

	Males				Females			
Location	N	Mean	SD	Range	N	Mean	SD	Range
				1994				
Mainstem	81	518.7	57.3	330-600	78	510.9	41.6	342-592
Right Fork	238	526.0	66.5	302-638	265	505.2	42.4	310-638
				1995				
Left Fork	7	530.7	98.4	346-608	0	---	---	---
Right Fork	565	523.9	70.4	297-650	776	532.8	27.8	421-598
				1996				
Left Fork	16	522.5	70.7	410-595	5	517.0	24.7	468-533
Right Fork	436	558.5	65.2	287-638	686	542.2	25.1	403-610
Moffet Springs	43	558.0	61.4	329-632	40	534.2	35.7	444-586

Length and Age Distribution.—Because of sample timing and sample sizes, comparisons of length and age distributions between locations were limited to the right fork and Moffet Springs Creek in 1996, although data for all 3 years are presented here (Tables 3 and 4 and Figures 12 and 13). In 1996, male and female sockeye salmon captured in the right fork were not different than males (t = 0.047, P = 0.962) and females (t = 1.39, P = 0.172) captured in Moffet Springs Creek (Table 3).

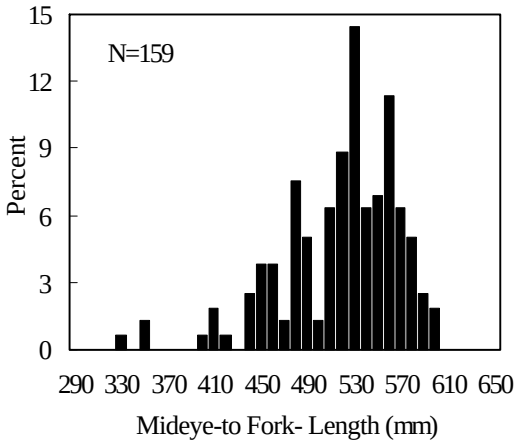

Figure 12. Length frequency for sockeye salmon captured in the mainstem of the Joshua Green River, 1994.

Ten age classes were represented by sockeye salmon sampled from both forks and Moffet Springs Creek in 1994-1996 (Table 4). With a few exceptions, the predominate age classes in all locations and years were 1.2 and 1.3. In 1994, the predominate age class in both locations was 1.2, but in addition to age 1.3, age 0.3 was also abundant in the mainstem (Table 4). In 1995, the modal age class in the right fork was 1.3, and with the exception of males in Moffet Springs Creek, the modal age for sockeye salmon in 1996 was also 1.3 (Table 4). The modal age for males in Moffet Springs Creek was 1.2 (Table 4).

Coho Salmon

Run Timing and Sex Composition.—In 1994, the coho salmon run in the mainstem began late August, and the weekly catch was still increasing when the field season was terminated September 12 (Figure 14). In

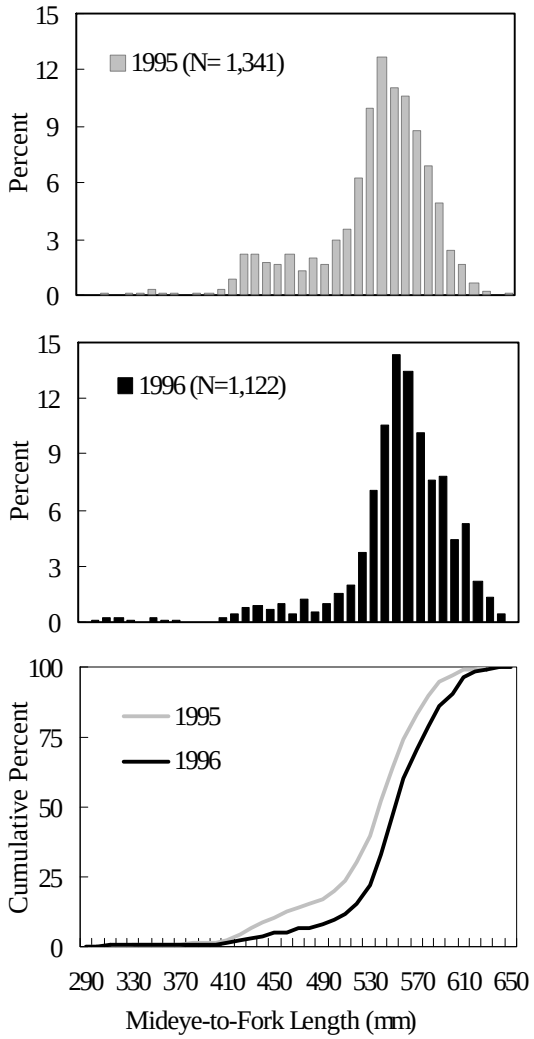

Figure 13. Length frequency and cumulative length frequency for sockeye salmon captured int the right fork of the Joshua Green River, 1995-1996.

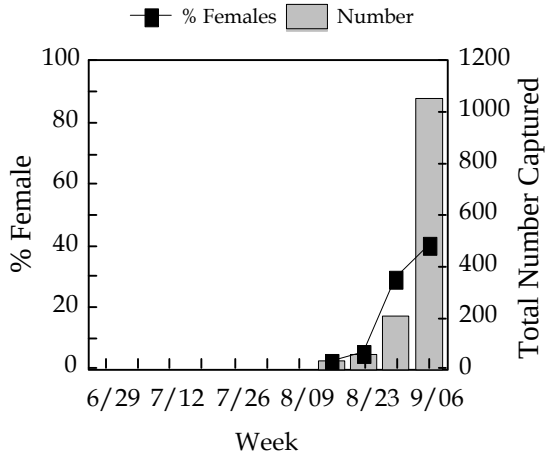

Figure 14. Coho salmon run timing (total number captured) and sex composition (% female) in the mainstem of the Joshua Green River, 1994.

1995, coho salmon were captured in both forks, but there was a preference for the right fork (Figure 15). Although the run was smaller in the left fork, run timing was similar in both forks. Coho salmon were first captured in both forks the third week of August and because the field season was terminated September 23 the decline seen the last week of sampling in both forks may not indicate the peaks of the runs had occurred. In 1996, coho salmon were first captured in both forks the second week of August, but in Moffet Springs Creek they were captured a week earlier (Figure 16). In the left fork coho salmon weekly capture rates peaked during early September, and had declined by early October (Figure 16). Coho salmon catch rates in the right fork and Moffet Springs Creek peaked the second week of September (N = 1,321) and quickly declined the following week.

In 1994, the percent of females in the Joshua Green River increased from 2.4% early in the run to 40.5% when the field season was terminated (Figure 14). The percent of females in the right fork generally increased throughout the 1995 season (11.8-46.4%; Figure 15). No clear patterns were seen in the left fork, but only 2 weeks had total catches >30 fish. In 1996, the percent of females generally increased throughout the season in the right fork(17.6-53.4%) and Moffet Springs Creek (44.9-57.7%; Figure 16), but no clear patterns were seen in the left fork because there were only 3 weeks

Table 4. Male and female sockeye salmon age composition (%) and sample sizes (N) for three locations in the Joshua Green River Drainage, 1994-1996.

	1994		1995	1996	
Age and	Right Fork	Mainstem	Right Fork	Right Fork	Moffet Springs
0.2					
Male	5.7	17.0	1.4	0.0	3.3
Female	2.6	5.1	0.9	0.0	0.0
0.3					
Male	1.9	21.3	1.4	5.4	3.3
Female	1.3	20.5	0.4	4.7	5.7
1.1					
Male	3.8	2.1	1.4	1.6	0.0
Female	10.4	0.0	0.4	0.0	0.0
1.2					
Male	71.7	38.3	35.9	23.2	43.3
Female	64.9	35.9	21.2	15.3	20.0
1.3					
Male	17.0	19.1	58.3	38.8	23.3
Female	13.0	33.3	76.6	46.8	40.0
1.4					
Male	0.0	0.0	0.7	2.3	0.0
Female	0.0	0.0	0.0	2.1	2.9
2.1					
Male	0.0	0.0	0.0	0.0	0.0
Female	3.9	0.0	0.0	0.0	0.0
2.2					
Male	0.0	2.1	0.7	5.4	3.3
Female	3.9	5.1	0.0	4.3	5.7
2.3					
Male	0.0	0.0	0.0	7.7	3.3
Female	0.0	0.0	0.5	9.8	14.3
3.3					
Male	0.0	0.0	0.0	0.0	0.0
Female	0.0	0.0	0.0	0.4	0.0
Unknown					
Male	---	---	---	20.0	13.2
Female	---	---	---	11.4	14.9
N					
Male	53	47	139	129	30
Female	77	39	222	235	35

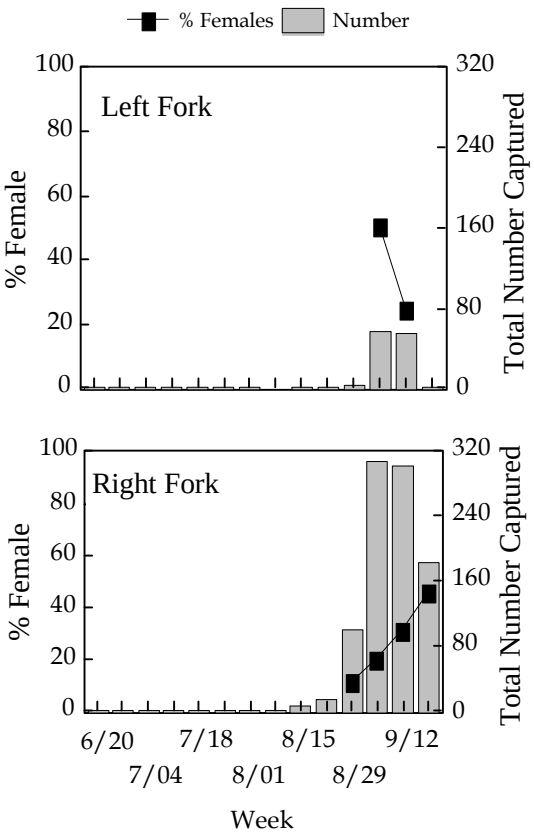

Figure 15. Coho salmon run timing (total number captured) and sex composition (% female) for the left and right forks of the Joshua Green River, 1995.

with total catches >30. Seasonal sex ratios were not determined because complete coverage of coho salmon runs did not occur in any year.

Length and Age Distributions.–No statistical comparisons of coho salmon mean MEF were made between locations for 1994 because the right fork was only sampled 4 weeks (Table 5 and Figure 17). In 1995, the mean MEF for male coho salmon captured in the left fork was larger than those captured in the right fork (t= 2.501, P = 0.013), but females captured in the two forks were not different (t = 1.754, P = 0.084; Table 5 and Figure 18). In 1996, the mean MEF for

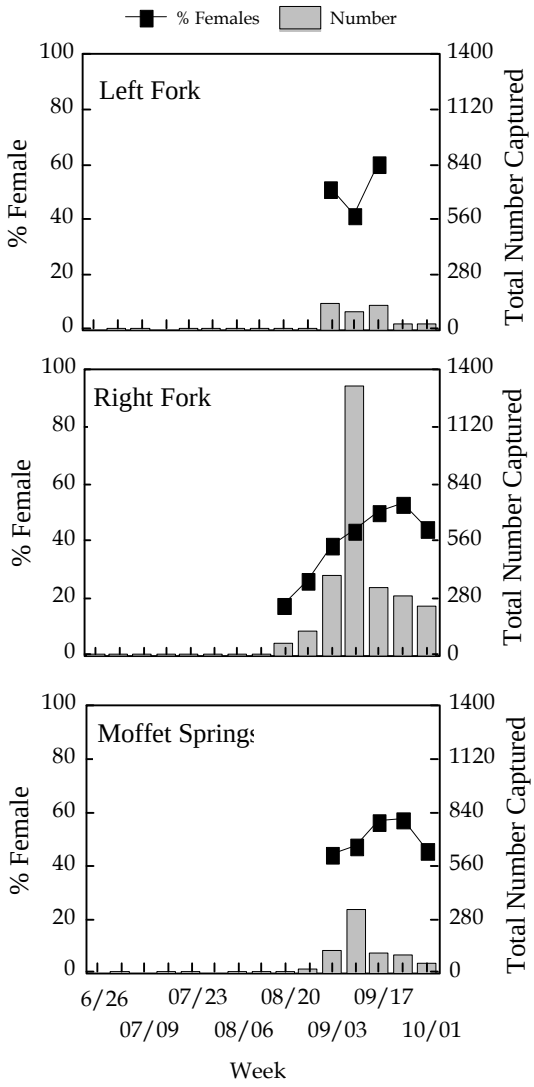

Figure 16. Coho salmon run timing (total number captured) and sex composition (% female) for three locations in the Joshua Green River drainage, 1996.

males in the left fork was smaller than males in the right fork (t = 3.119, P = 0.001) and Moffet Springs Creek (t = 2.996, P = 0.003), but the mean MEF for males captured in the right fork and Moffet Springs Creek were not different (t = 0.233, P = 0.816). No differences in the mean MEF were found for female coho sampled from all three locations (all $P \geq 0.180$; Table 5 and Figure 19).

Table 5. Coho salmon mean mid-eye to fork lengths (mm), standard deviations (SD), and ranges in the Joshua Green River drainage, 1994-1996.

	Males				Females			
Location	N	Mean	SD	Range	N	Mean	SD	Range
				1994				
Mainstem	680	609.7	57.5	337-728	386	634.9	36.5	515-713
				1995				
Left Fork	73	563.3	66.7	162-658	43	598.7	30.9	542-680
Right Fork	559	550.3	54.7	309-681	226	589.2	39.2	440-667
				1996				
Left Fork	186	583.9	96.8	285-722	216	634.3	49.7	304-707
Right Fork	767	603.2	73.5	291-755	594	639.3	39.9	452-725
Moffet Springs	314	609.4	83.2	186-723	303	634.5	36.0	365-723

Eight age classes were represented by coho salmon sampled from both forks and Moffet Springs Creek in 1994-1996, but not all age classes were found in all locations or years (Table 6). Age classes 1.1 and 2.1 were the predominate age classes in all 3 years, but there were variations between years and locations. Prior to 1996, age class 3.1 had only been represented by one fish in the 1994 mainstem sample, but in 1996 it was 9.8-12.2% of the samples from all three locations (Table 6).

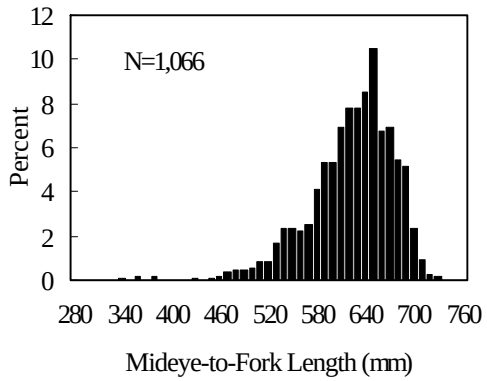

Figure 17. Length frequency length frequency for coho salmon captured in the mainstem Joshua Green River, 1994.

Pink Salmon

Run Timing and Sex Composition. Weekly catch rates for pink salmon were often < 30 fish in 1994 and 1995 limiting interpretation, but some similarities were seen between years and locations. Although capture locations were different, pink salmon were first captured in the Joshua Green River in early to mid-July all 3 years (Figure 20-22). In 1994, the peak capture rate in the mainstem occurred the third week of August (N = 18; Figure 20), while in 1995, the peak in the right fork occurred the fourth week of August (N = 57; Figure 21). In 1996, the peak catch in the right fork occurred the first week of August, which was earlier than the previous year, but the run was also larger (peak N = 447). Although weekly capture rates were low in Moffet Springs Creek in 1996, the peak capture rate (N = 20) and run duration were similar to the run in the right fork (Figure

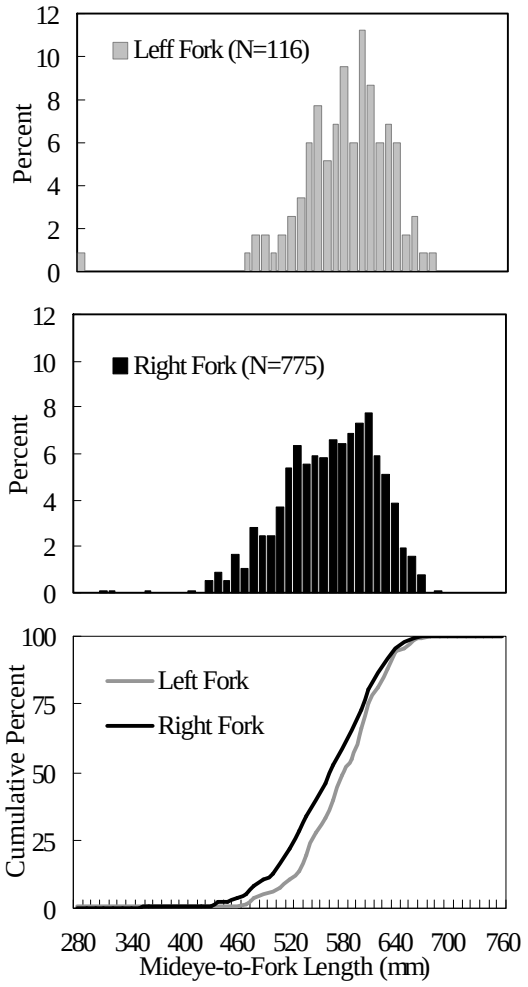

Figure 18. Length frequency and cumulative length frequency for coho salmon captured in the right and left forks of the Joshua Green River, 1995.

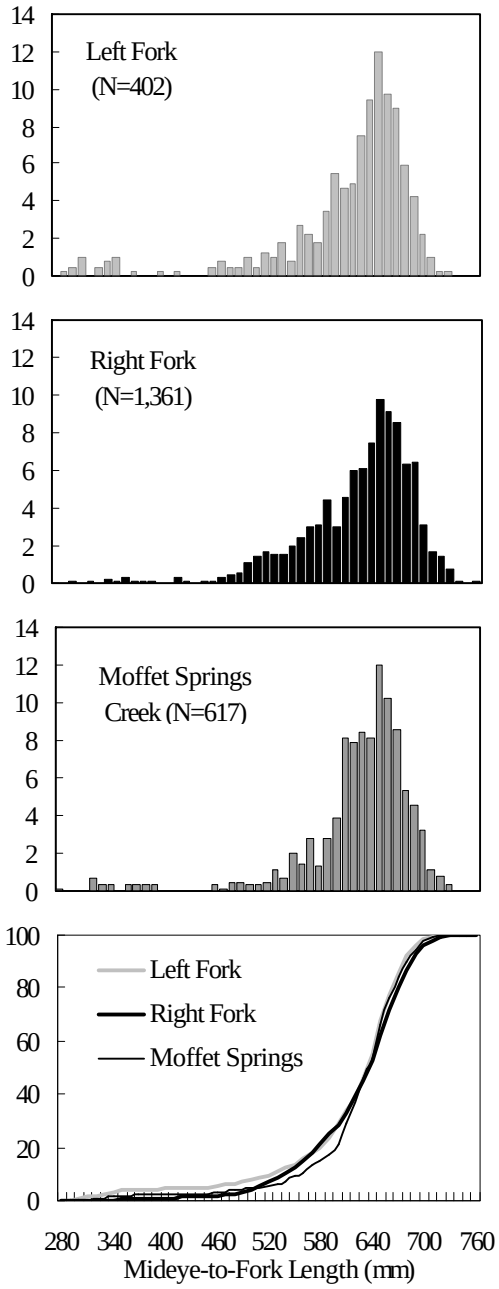

Figure 19. Length frequency and cumulative length frequency for coho salmon captured in three locations in the Joshua Green River drainage, 1996.

22). Small sample sizes also limited the interpretation of sex composition data, but using only 1996 data for the right fork, the percent of females in the weekly catch increased until the peak of the run at which time it began to oscillate (Figure 22).

Length Distributions. In 1994, the mean MEF in the mainstem was similar for male and female pink salmon (Table 7 and Figure 23). In 1995, no comparisons of mean MEF were made between locations because only six pink salmon were captured in the left fork. In 1996, the mean MEF's for male (t = 1.936, P = 0.054) and female (t = 0.243, P

Table 6. Male and female coho salmon age composition (%) and sample sizes for several locations in the Joshua Green River Drainage, 1994-1996.

Age and Sex	1994	1995		1996		
	Mainstem	Right Fork	Left Fork	Right Fork	Left Fork	Moffet Springs
1.0						
Male	0.0	0.0	1.6	0.0	0.0	0.0
Female	0.0	0.0	0.0	0.0	0.0	0.0
1.1						
Male	64.3	60.4	49.2	21.0	15.9	11.4
Female	59.0	42.7	48.6	15.7	9.9	7.9
1.2						
Male	0.0	0.0	0.0	0.0	0.0	0.0
Female	1.6	0.0	0.0	0.0	0.0	0.0
2.0						
Male	0.6	0.0	0.0	0.4	6.1	3.8
Female	0.0	0.0	0.0	0.0	0.0	0.0
2.1						
Male	35.1	39.6	49.2	46.8	43.9	59.2
Female	37.7	57.3	51.3	61.5	64.8	62.6
3.0						
Male	0.0	0.0	0.0	0.0	0.0	0.5
Female	0.0	0.0	0.0	0.0	0.0	0.0
3.1						
Male	0.0	0.0	0.0	11.6	13.6	9.9
Female	1.6	0.0	0.0	7.6	11.1	14.7
4.1						
Male	0.0	0.0	0.0	0.0	0.0	0.0
Female	0.0	0.0	0.0	0.4	0.0	0.0
Unknown						
Male	---	---	---	20.2	20.5	15.2
Female	---	---	---	14.8	14.2	14.7
N						
Male	168	212	63	267	132	211
Female	61	82	37	223	162	190

= 0.809) pink salmon captured in Moffet Springs Creek and the right fork were not different (Table 7 and Figure 24). No statistical comparisons were made with the left fork because sample sizes were <30 fish.

Dolly Varden Char

Run Timing. In 1994, Dolly Varden char were first captured in the mainstem in late June, and capture rates peaked the second week of August (Figure 25). In

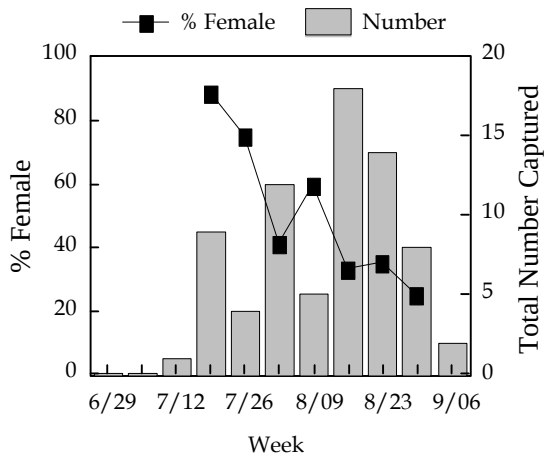

Figure 20. Pink salmon weekly run timing (total number captured) and sex composition (% female) in the mainstem of the Joshua Green River, 1994.

1995 and 1996, few Dolly Varden char were captured in any location until late June or early July (Figures 26 and 27). Capture rates in the lower left fork appeared to peak in mid-August in 1995 and late-July in 1996 and then decline in late August both years. In 1995 and 1996, weekly capture rates in

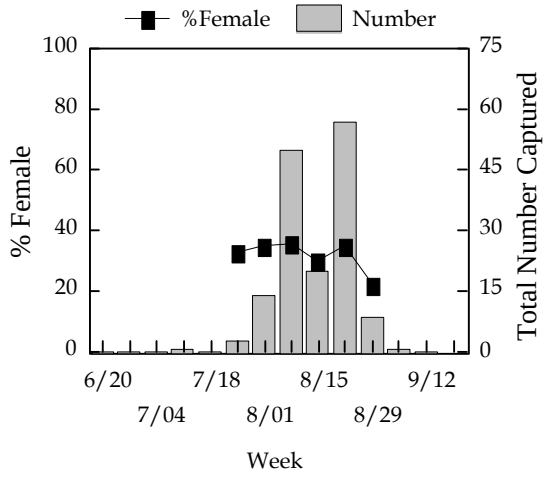

Figure 21. Pink salmon weekly run timing (total number captured) and sex composition (% female) in the right fork of the Joshua Green River, 1995.

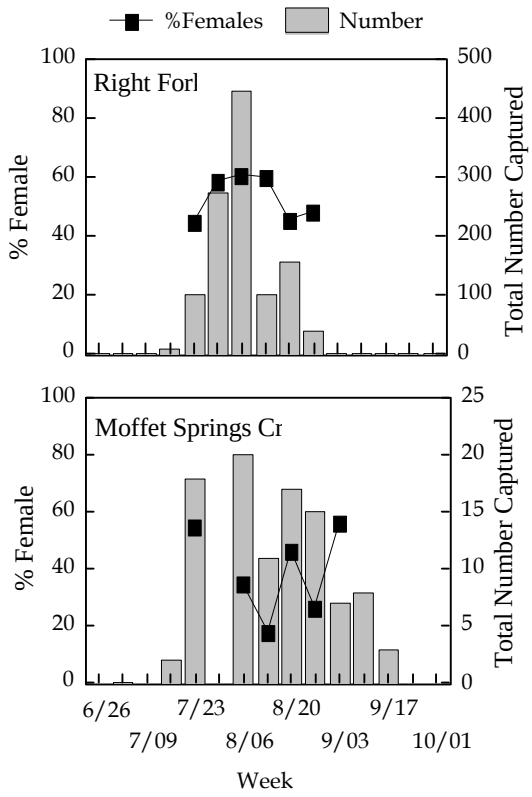

Figure 22. Pink salmon weekly run timing (total number captured) and sex composition (% female) in the right fork of the Joshua Green River and Moffet Springs Creek, 1996.

the lower right fork were more variable. In 1995, peak capture rates occurred in late July, but in 1996 there was no obvious peak. In 1996, Moffet Springs Creek weekly catch appeared to peak in mid-July and decline by mid to late August, but sampling was sporadic early in the season (Figure 27).

Length and Age Distributions. In 1994, adult Dolly Varden char were only captured in the mainstem of the Joshua Green River so no comparisons were made (Table 8 and Figure 28). In 1995, char were captured in two locations on each fork (upper and lower), and those captured in the upper locations were larger (mean FL) than those in the lower locations (left fork: $t = 9.112$, $P < 0.001$; right fork: $t = 9.065$, $P < 0.001$;

Table 7. Pink salmon mean mid-eye to fork lengths (mm), standard deviations (SD), and ranges in the Joshua Green River drainage, 1994-1996.

	Males				Females			
Location	N	Mean	SD	Range	N	Mean	SD	Range
				1994				
Right Fork	132	481.4	35.9	378-581	99	474.5	22.7	385-522
Mainstem	39	466.3	32.0	400-530	34	468.6	23.1	418-510
				1995				
Right Fork	102	478.0	42.5	386-571	54	467.2	42.3	325-533
				1996				
Left Fork	5	478.8	24.1	440-515	7	474.4	19.0	435-501
Right Fork	286	472.0	34.4	352-566	333	466.3	22.8	392-552
Moffet Springs	62	481.3	33.3	403-538	39	467.6	32.3	361-523

Table 8). The mean FL of char captured in the left fork (both locations combined) was larger than mean FL of those captured in the right fork (t = 11.960, P <0.001; Table 8 and Figure 29). In 1996, Dolly Varden char were only captured in the lower section of both forks, but the mean FL of those captured in the left fork was larger than those captured in the right fork (t = 28.415, P <0.001) and Moffet Springs Creek (t = 6.296, P <0.001), and the mean FL of Dolly Varden char captured in Moffet Springs Creek was larger than those captured in the right fork (t = 19.373, P <0.001; Table 8 and Figure 30). Otoliths were collected from 74 Dolly Varden char in 1995 and 115 in 1996. Seven different age classes were represented by the otolith samples (Table 9). Age 4 char were the most abundant in the 1995 sample, and ages 4 and 5 the most abundant in 1996 (Table 9). The mean length at age was larger for older fish, but the length ranges for each age class overlapped considerably (Table 9).

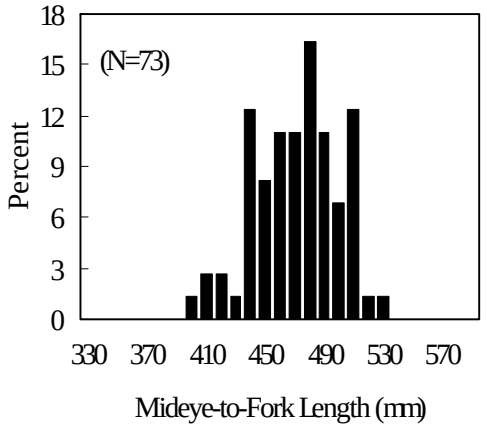

Figure 23. Length frequency for pink salmon captured in the mainstem of the Joshua Green River, 1994.

Movement.—In 1995, Dolly Varden char were tagged in the lower sections of the left (N = 365) and right fork (N = 453). During the summer, 18 tagged fish were recaptured in either the upper or lower sections of both forks. Five fish were recaptured in the lower left fork, four of which were tagged in the lower left fork and one in the lower right fork. Three tagged fish were recaptured in the upper left fork, and they were all tagged in the lower left fork. One fish was recaptured in the lower right fork where it

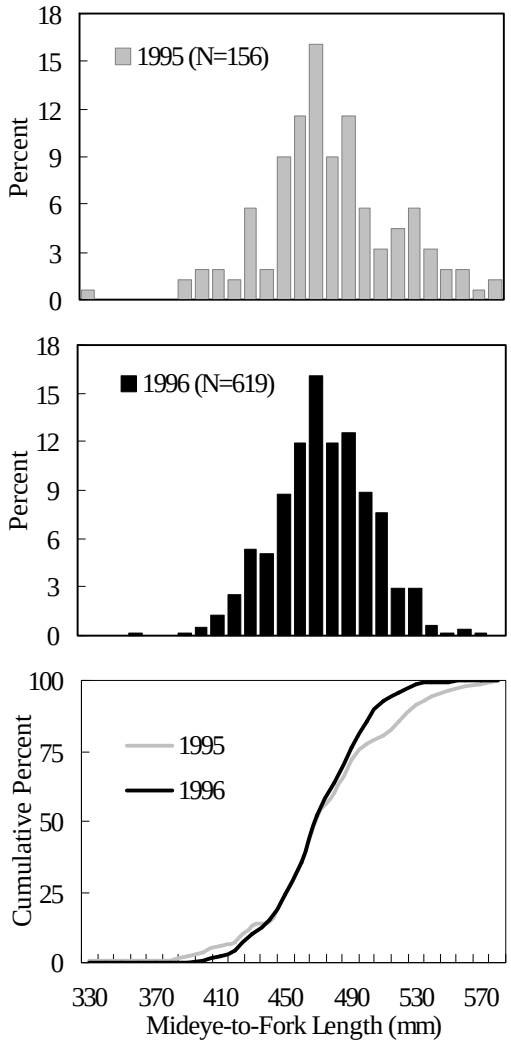

Figure 24. Length frequency and cumulative length frequency for pink salmon captured in the right fork of the Joshua Green River, 1995-1996.

had also been tagged. The remaining nine fish were recaptured in the upper right fork. Eight of which had been tagged in the lower right fork, and one in the lower left fork. In summary, of the 18 recaptured fish, two moved upstream to the upper section of the fork where it had been tagged. In 1996, an additional 349 Dolly Varden char were tagged in the right fork and 499 in the left fork. Sixteen Dolly Varden char tagged in 1995 were recaptured in 1996. Thirteen

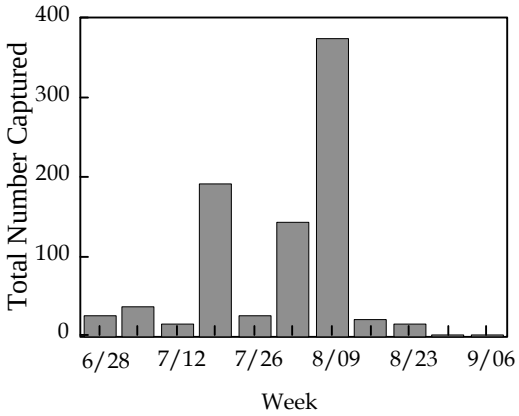

Figure 25. Dolly Varden char run timing (total number captured) in the mainstem of the Joshua Green River, 1994.

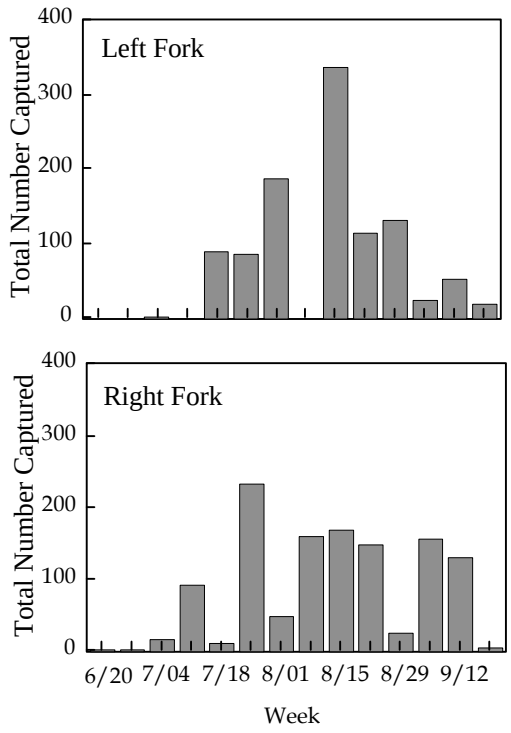

Figure 26. Dolly Varden char run timing (total number captured) in the lower sample site of the right and left forks of the Joshua Green River, 1995.

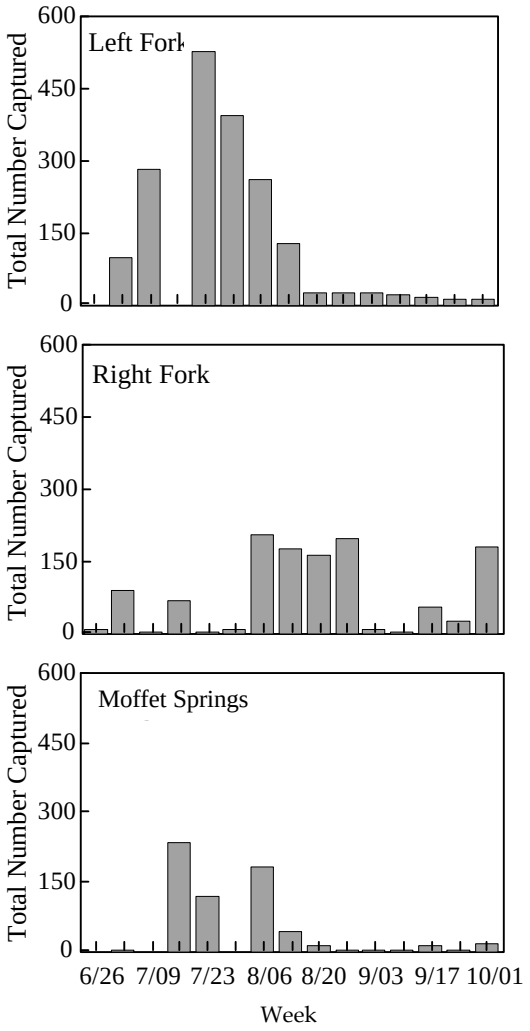

Figure 27. Dolly Varden char run timing (total number captured) in three locations in the Joshua Green River drainage, 1996.

were recaptured in the left fork and three in the right fork. All of the tagged fish were recaptured in the same fork where they were tagged in 1995. Eight of the fish tagged during the 1996 field season were recaptured again that summer. Two of the fish tagged in the lower left fork had moved into the lower right fork, but all of the char recaptured in the left fork were tagged there earlier in the season.

Discussion

Pacific Salmon

Chum, sockeye, coho, and pink salmon were captured in the Joshua Green River and Moffet Springs Creek in 1994-1996. Historically chinook salmon were also reported in the Joshua Green River, but no adult or juvenile chinook salmon were captured during this study. The historical reports of chinook salmon were based on aerial surveys; therefore, it is possible that other species of Pacific salmon were misidentified as chinook salmon (A. Shaul, Alaska Department of Fish and Game, personal communication). Without on-the-ground verification, it is not possible to document that chinook salmon were present in the Joshua Green River.

Chum salmon runs in the Joshua Green River began late June all 3 years. In 1994, a bimodal capture distribution for chum salmon indicated there may be two runs of chum salmon; therefore, sample locations were changed to the right and left forks in 1995 and 1996. Run timing and length data supported the possibility of two separate runs. The early run, which appears to peak in mid August, had a preference for the right fork, while the late run which peaked in early September preferred the left fork. Capture rates also increased in the right fork in mid-August, but without a method to distinguish fish from both runs it was not possible to determine whether increasing catch was the result of fish from the late run entering the right fork or new fish from the early run. The percent of females captured in both forks and Moffet Springs Creek generally increased during the run. In addition to differences in run timing, there were also differences in the mean MEF and age of chum salmon captured in the right and left

Table 8. Adult Dolly Varden char mean fork length (mm), standard deviations (SD) and ranges in the Joshua Green River drainage, 1994-1996.

	Length (mm)			
Location	N	Mean	SD	Range
			1994	
Mainstem	640	399.0	71.8	195-604
			1995	
Left Fork (Upper)	289	460.6	60.2	232-634
Left Fork (Lower)	813	421.1	71.2	215-628
Total Left Fork	1,102	431.5	70.7	215-634
Right Fork (Upper)	1,026	412.2	76.7	228-658
Right Fork (Lower)	1,044	378.5	91.8	223-674
Total Right Fork	2,070	395.2	86.3	223-674
			1996	
Left Fork (Lower)	1,102	447.7	63.3	254-654
Right Fork (Lower)	789	352.1	82.9	180-631
Moffet Springs Creek	567	429.1	53.7	293-607

forks. Male chum salmon captured in the right fork were larger in 1995 and 1996, and females were larger in the right fork in 1995. During both years, there was a higher percentage of age 0.2 and 0.3 male chum salmon captured in the left fork, while age 0.4 and 0.5 male chum salmon were more abundant in the right fork. The age composition for chum salmon captured in the Joshua Green River and Moffet Springs Creek was similar to other populations (Salo 1991).

Table 9. Dolly Varden char mean fork length (mm) at age based on otolith samples collected from the right and left forks of the Joshua Green River, 1995-1996.

	1995				1996			
Age	N	Mean	SD	Range	N	Mean	SD	Range
3	17	306.9	47.5	247-410	21	343.9	47.6	254-440
4	29	379.4	56.4	240-543	35	371.3	34.3	304-469
5	18	442.3	62.2	268-550	37	408.4	56.0	281-503
6	8	501.7	58.5	415-605	18	468.9	42.4	369-531
7	---	---	---	---	4	503.2	23.8	466-532
8	1	545.0	---	---	1	487.0	---	---
9	---	---	---	---	1	605.0	---	---

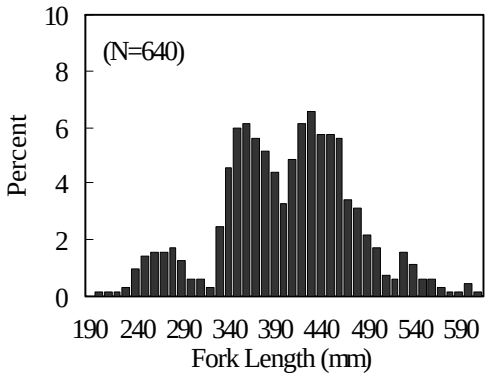

Figure 28. Length frequency for Dolly Varden char captured in the mainstem of the Joshua Green River, 1994.

The sockeye salmon run in the Joshua Green River and Moffet Springs Creek began late June and peaked in mid July, 1994-1996. During all 3 years, the percent of females captured was variable throughout the run, with no clear patterns. Sockeye salmon used primarily the right fork of the Joshua Green River, and this preference was likely related to the association of the right fork with Paul Hansen Lake. Sockeye salmon spawning is often associated with lakes which provide important rearing habitat for juveniles. Although there are small tundra ponds associated with the left fork and Moffet Springs Creek, they may provide limited rearing habitat for sockeye salmon. Ages 1.2 and 1.3 were the predominant age classes in all locations and years, but several other age classes were represented. Age 0.2 and 0.3 adult sockeye salmon were captured in both forks and Moffet Springs Creek, but their numbers were small in 1995 and 1996. However, in 1994, 20.5-21.3% of the males and females sampled in the mainstem were age 0.3 and another 17.0% of the males were age 0.2. Age 0. sockeye salmon are unique, and are

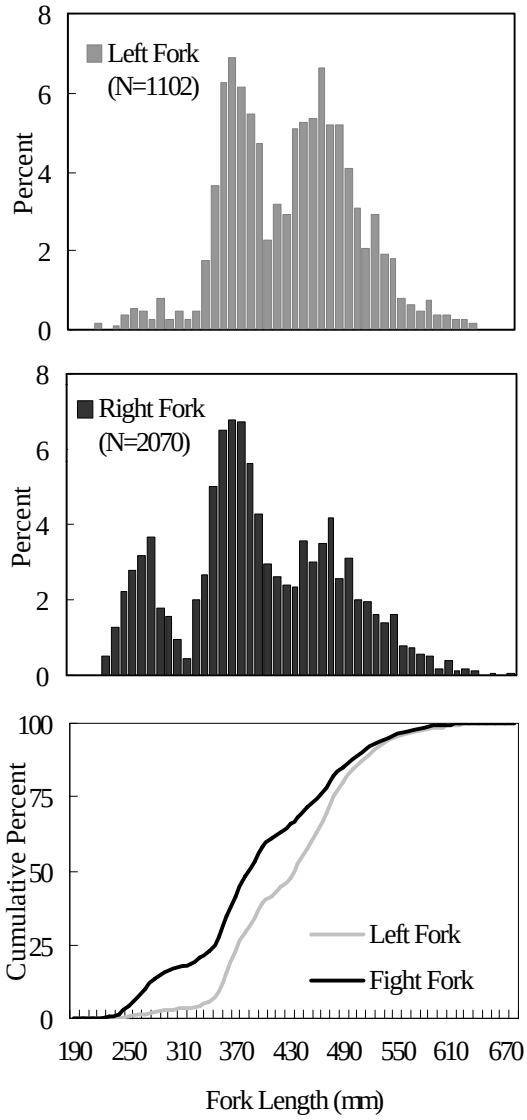

Figure 29. Length frequency and cumulative length frequency for Dolly Varden char in the right and left forks of the Joshua Green River, 1995.

usually found in systems without lake access (Burgner 1991). The variety of age classes indicates different life histories which are often related to juvenile rearing conditions. Sockeye salmon often exhibit a greater variety of life history patterns than other Pacific salmon (Burgner 1991).

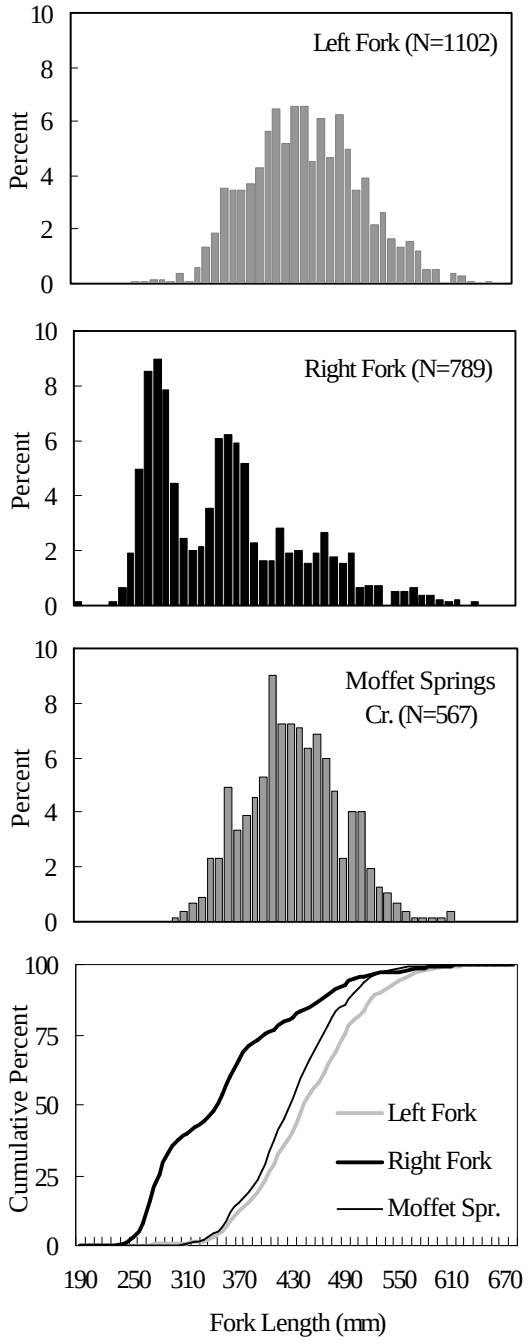

Figure 30. Length frequency and cumulative length frequency for Dolly Varden char captured in the right and left forks of the Joshua Green River and Moffet Springs Creek, 1996.

The Joshua Green River coho salmon run began mid to late August, and the percent of females generally increased throughout the run during all 3 years. However, sampling was terminated prior to the end of the run all 3 years. Run timing and sex, age, and length compositions can all vary throughout the run; therefore, without complete coverage of the run, sampling results may not have provided an accurate description of the coho salmon populations in the Joshua Green River and Moffet Springs Creek. Coho salmon showed a strong preference for the right fork, but they were also abundant in the left fork. Without additional sampling, it is impossible to know whether late returning coho salmon have a preference for the left fork. Many variables including sex, age, and time position in the run can influence the size of returning coho salmon (Sandercock 1991).

Pink salmon runs in the Joshua Green River and Moffet Springs Creek were smaller than runs of other salmon species. As with coho and sockeye salmon, pink salmon preferred the right fork. Weekly catch rates were often <30 fish, limiting meaningful comparisons between locations. Pink salmon runs in the Joshua Green River drainage began early to mid-July all 3 years, but the run peaks were variable between years (early to late August). Small sample sizes limited interpretation of sex composition data to the 1996 run in the right fork. The percent of females generally increased to the peak of the run, at which time it began to oscillate.

Dolly Varden Char

Dolly Varden char were captured in the Joshua Green River and Moffet Springs Creek. Adult and sub-adult Dolly Varden char do not appear to overwinter in the Joshua Green River because few were captured before mid-July in any sampling

year. Although, it was possible that they overwintered in areas that were not sampled. Unlike adult Pacific salmon, there did not appear to be a preference for either fork. The total number captured was greater in the right fork in 1995, but this apparent inequity may be caused by sampling bias. Both locations sampled in the right fork were sampled more often than those in the left fork, and only the lower right fork was sampled all 14 weeks. This sampling bias also occurred in 1996, but despite fewer sampling days, total catch was higher in the left fork. In 1995 and 1996, Dolly Varden char captured in the lower section of the left fork were larger than those captured in the lower right fork. Fork length frequency distributions indicated that smaller Dolly Varden char (approximately 190-310mm) were more abundant in the right fork.

To determine movements within the Joshua Green River, Dolly Varden char were tagged in the lower sections of both forks in 1995 and 1996. Tagging was not the primary focus of this study so findings were limited. Few fish were recaptured either year, but movement appears limited within the drainage. Most recaptured fish were tagged in the same fork where they were recaptured and often within the same initial capture location. However, some movement was seen within and between the right and left forks. In addition, one Dolly Varden char tagged in the Joshua Green River was recaptured in Frosty Creek, located southwest of the town of Cold Bay. This recapture indicates that there was also some movement between drainages.

Sampling Problems

A few logistical problems may have biased sample results in the Joshua Green River. First, gear saturation occurred during the peaks of the chum and coho salmon runs, and hundreds of fish were dumped from the net to avoid stressing fish retained for sampling. Removal of the fish was not truly random, and may have biased the age, length and sex compositions of remaining fish. However, gear saturation occurred only a few weeks during the peak of the chum and coho salmon runs and seasonal sample sizes were often very large; therefore, the actual bias may have been minimal. Chum salmon age and sex compositions in the Joshua Green River drainage were similar to other salmon populations, and mean MEF was also similar to other populations (Salo 1991).

Second, sampling for coho salmon was terminated prior to the end of the run all 3 years; therefore, the results may not accurately describe the population in the Joshua Green River drainage. Age compositions were fairly similar to other populations but they were variable among years. Very few or no age 3.1 coho salmon were captured in 1994 and 1995, but in 1996 they were >14% of the fish sampled in all three locations.

Third, sample dates were missed in the left fork and Moffet Springs Creek in 1995 and 1996. In the left fork, there was one week missed both years, but for most species that week was very early in the run and did not affect comparisons between forks. For sockeye salmon, the date missed in the left fork in 1995 occurred while numbers were increasing in the left fork, but catch rates for all weeks before and after were so low it is unlikely that the overall results would have been different. In 1996, two weeks were missed in Moffet Springs Creek. Chum salmon and sockeye salmon run timing and sex composition may have been biased because one of those weeks either occurred as weekly catch rates were increasing or

peaking. Finally, high water levels during coho salmon sampling made effective sampling difficult and capture rates may have been subsequently lower.

Recommendations

Although estimating escapement was not the intent of this project, the results indicated that chum and coho salmon were the predominate salmon species in the Joshua Green River. Current management, based on aerial surveys and commercial catch per unit effort data, focuses primarily on chum and sockeye salmon escapement (Alaska Department of Fish and Game 1993). Although it is unlikely that current management is adversely affecting the abundant coho salmon run, the information should be incorporated into future management decisions. In addition, current management is based on the total chum salmon escapement within the drainage, and does not account for possible differences between the right and left forks. If there are two separate populations in the Joshua Green River, current management could adversely affect one or both populations. Determining whether there are genetically different populations in the right and left fork is important for the long term management of the Joshua Green River drainage.

Additional sampling may also be necessary to understand the apparent preference for the right fork of the Joshua Green River. Identifying and quantifying important habitats for adults and juveniles was not an objective of this study, but this information is necessary to completely understand the differences found between sample locations. In addition, complete coverage of the coho salmon run is necessary to accurately describe this population.

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