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Estimating the Spawning Distribution of Pacific Salmon in the Matanuska River Watershed, Southcentral Alaska, 2008

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Abstract

The Matanuska River is a significant physical feature of northern Cook Inlet, yet very little is known about salmon distribution, run timing, or abundance. This project was implemented to provide fishery managers with baseline data regarding the relative run strength and spawning distribution of chum *Oncorhynchus keta*, coho *O. kisutch*, and sockeye salmon *O. nerka* in the Matanuska River watershed. A fishwheel was used to capture fish and radio telemetry was used to uniquely identify and track individual chum, coho, and sockeye salmon to spawning destinations upstream of the tagging site on the Matanuska River. We operated a live capture fishwheel at river km 19 on the Matanuska River for 367.7 hours from 22 July through 22 September and a total of 194 chum, 461 coho, and 350 sockeye salmon were captured. A total of 294 radio transmitters were deployed in chum, coho, and sockeye salmon between 29 July and 17 September 2008 and 263 fish were successfully tracked to spawning areas. Over 90% of chum (n = 42) and 98% of sockeye salmon (n = 81) selected spawning locations in the mainstem braid plain of the Matanuska River while 56% of coho salmon (n = 75) selected spawning locations in tributary watersheds. Clearwater side channels associated with the mainstem braid plain provide important spawning habitat for Pacific salmon in the Matanuska River watershed and probably provide important rearing habitat. This project supports goals and objectives of the Matanuska-Susitna Basin Salmon Habitat Partnership and the National Fish Habitat Action Plan by providing data on salmon distribution, stock status, and abundance and by identifying critical spawning habitat. Knowledge of important habitat allows local land managers and planners to better protect and conserve salmon habitat from current and future development activities in the Matanuska River watershed.

Introduction

The human population of the Matanuska-Susitna (Mat-Su) Borough is one of the fastest growing in the U.S., with a growth rate of 49% from 1990 to 2000 (U. S. Census Bureau 2001). A combination of proximity to Anchorage, a rural setting, and lower housing prices is likely stimulating the rapid growth. The city of Palmer and the communities of Sutton and Chickaloon are the major population centers in the Matanuska River watershed. Rapid population growth and the accompanying pressures for development will increasingly challenge the ability of fisheries and land managers to balance fish habitat conservation with these changes over time. Maintaining healthy fish habitat, including water quality and quantity, is critical to maintaining healthy fish populations in the Matanuska River watershed.

Major human activities that affect fish habitat in the Matanuska River watershed are associated with residential and urban development. Development and land uses associated with housing and urban areas include the clearing of land, construction of buildings, and various activities on those cleared lands that have direct and indirect impacts on waterbodies. The primary effects of housing and urban development on salmon and their habitat are the loss of wetlands, alteration of

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riparian habitat, degraded water quality, and creation of impervious surfaces (MSBSHP 2008). The Glenn Highway provides access along most of the length of the Matanuska River and secondary road construction for housing, urban, and industrial development and for the development of natural resources will continue as the population in the area continues to grow.

The Matanuska River watershed is rich in coal and other natural resources and coal mining was historically significant to the economy of the area. In the 1910s, the U.S. Navy's need for coal for its Pacific Fleet led to the development of the Alaska railroad from Seward to Chickaloon and the development of the coal towns of Sutton and Chickaloon. Coal mining activity waned in the 1920s but continued within the watershed until the mid 1980s. Although there are no active coal mines in the Matanuska River watershed, coal mining in the watershed may again become economically feasible in the future. The local electric utility recently proposed a plan to construct a coal-fired power plant in the Mat-Su Borough within the next decade. In addition to coal resources, sand and gravel mining occurs today in numerous areas of the watershed, with increased interest from the gravel industry to mine within the Matanuska River braid plain.

The Matanuska River is a significant physical feature of northern Cook Inlet, yet very little is known about salmon distribution, timing, or abundance. Pacific salmon *Oncorhynchus* spp. from the Matanuska River contribute to commercial fisheries in Upper Cook Inlet, mainly in mixed-stock set and drift gillnet fisheries for sockeye *O. nerka* and coho *O. kisutch* salmon. Most Upper Cook Inlet commercial sockeye salmon fisheries target stocks returning to the Kasilof and Kenai rivers, although the contribution of Matanuska River stocks is unknown. Total commercial harvest of coho salmon in Upper Cook Inlet averaged nearly 250,000 fish per year from 1994 to 2003 (Fox and Shields 2005), but the portion of those fish bound for the Matanuska River is unknown. Previous research indicates that the Central District drift net and Northern District west-side set net fisheries harvest mainly coho salmon bound for northern Cook Inlet, particularly the Susitna River (Vincent-Lang and McBride 1989). Willette et al. (2003) estimated that the Matanuska River coho salmon escapement was about 20,000 fish, which comprised 8% of the Knik Arm escapement and about 2% of the overall upper Cook Inlet escapement. However, to date there have been no direct measures of Matanuska River chum *O. keta*, coho, or sockeye salmon run timing or escapements. Sport harvest of salmon in the Matanuska River is minimal (Sweet et al. 2003).

Concerns for how to effectively protect and restore salmon production in the face of rapid development of these drainages led to the creation of the Mat-Su Basin Salmon Habitat Partnership (MSBSHP). This partnership is one of the fish habitat partnerships approved nationwide under the National Fish Habitat Action Plan (NFHAP). The NFHAP is a national effort to protect and restore the nation's waterways and fisheries through science-based partnerships of affected stakeholders. The MSBSHP has developed a Strategic Action Plan, which identifies objectives, actions, and research necessary to protect salmon and salmon habitat in the Mat-Su basin (MSBSHP 2008).

This project was implemented to provide fishery and land managers with baseline data regarding the relative run strength, run timing, and spawning distribution of chum, coho, and sockeye salmon in the Matanuska River watershed and to provide baseline data regarding relative run strength of other anadromous species. This report summarizes our efforts to meet the following objectives in 2008:

1. Evaluate the effectiveness of fishwheels to capture adequate numbers of chum, coho, and sockeye salmon for tagging in the Matanuska River;
2. Estimate the migratory timing profiles of chum, coho, and sockeye salmon in the Matanuska River at the point of capture from July through mid October 2008;
3. Detect the ultimate spawning destination upstream of the Old Glenn Highway Bridge (river km 19), via the presence of at least one tagged fish, of a population comprising 10% or more of all the chum salmon passing the capture site during each temporal stratum with probability 0.85;
4. Detect the ultimate spawning destination upstream of the Old Glenn Highway Bridge (river km 19), via the presence of at least one tagged fish, of a population comprising 10% or more of all the coho salmon passing the capture site during each temporal stratum with probability 0.85;
5. Detect the ultimate spawning destination upstream of the Old Glenn Highway Bridge (river km 19), via the presence of at least one tagged fish, of a population comprising 10% or more of all the sockeye salmon passing the capture site during each temporal stratum with probability 0.85;
6. Map chum, coho, and sockeye salmon spawning areas of the mainstem Matanuska River and its tributaries;
7. Estimate the sex, age, and length compositions of chum, coho, and sockeye salmon in the Matanuska River; and
8. Determine the feasibility of obtaining a spawning abundance estimate for chum, coho, and sockeye salmon using mark-recapture techniques in the Matanuska River watershed.

Fishwheels have been used successfully to capture migrating salmon for tagging and estimation of migratory timing in similar projects for the Copper (Savereide 2005; Wade et al. 2007), Yukon (Apodaca and Daum 2006; Cleary and Hamazaki 2007), Kuskokwim (Pawluk et al. 2006), Susitna (Yanusz et al. 2007), and Nass (Link and English 1996, 2000) rivers. Radio telemetry was used to uniquely identify and track individual chum, coho, and sockeye salmon to spawning destinations upstream of the tagging site on the Matanuska River. Movements and final spawning destinations of radio-tagged fish were documented using a combination of fixed data-logging receiver stations and aerial and ground-based mobile tracking.

Study Area

The Matanuska River watershed drains over 5,300 km^2 within the Cook Inlet drainage basin of southcentral Alaska (Figure 1). The headwaters of the Matanuska River originate at over 3,000 m in the Chugach Mountains and the river flows westward for more than 120 km where it joins the Knik River and flows into Knik Arm of Cook Inlet. The watershed is bounded to the north by the Talkeetna mountain range and to the south by the Chugach mountain range. The Chickaloon River, with its headwaters in the Talkeetna Mountains, is the largest tributary to the Matanuska River.

The Matanuska River is a typical glacial river with braided channels, shifting substrates, an overall lack of pool habitat, and is generally less stable than snowmelt or rain dominated systems (Milner and Petts 1994). These physical characteristics are thought to make glacial rivers unsuitable for fish habitat, and high turbidity in glacial systems also contributes to reduced

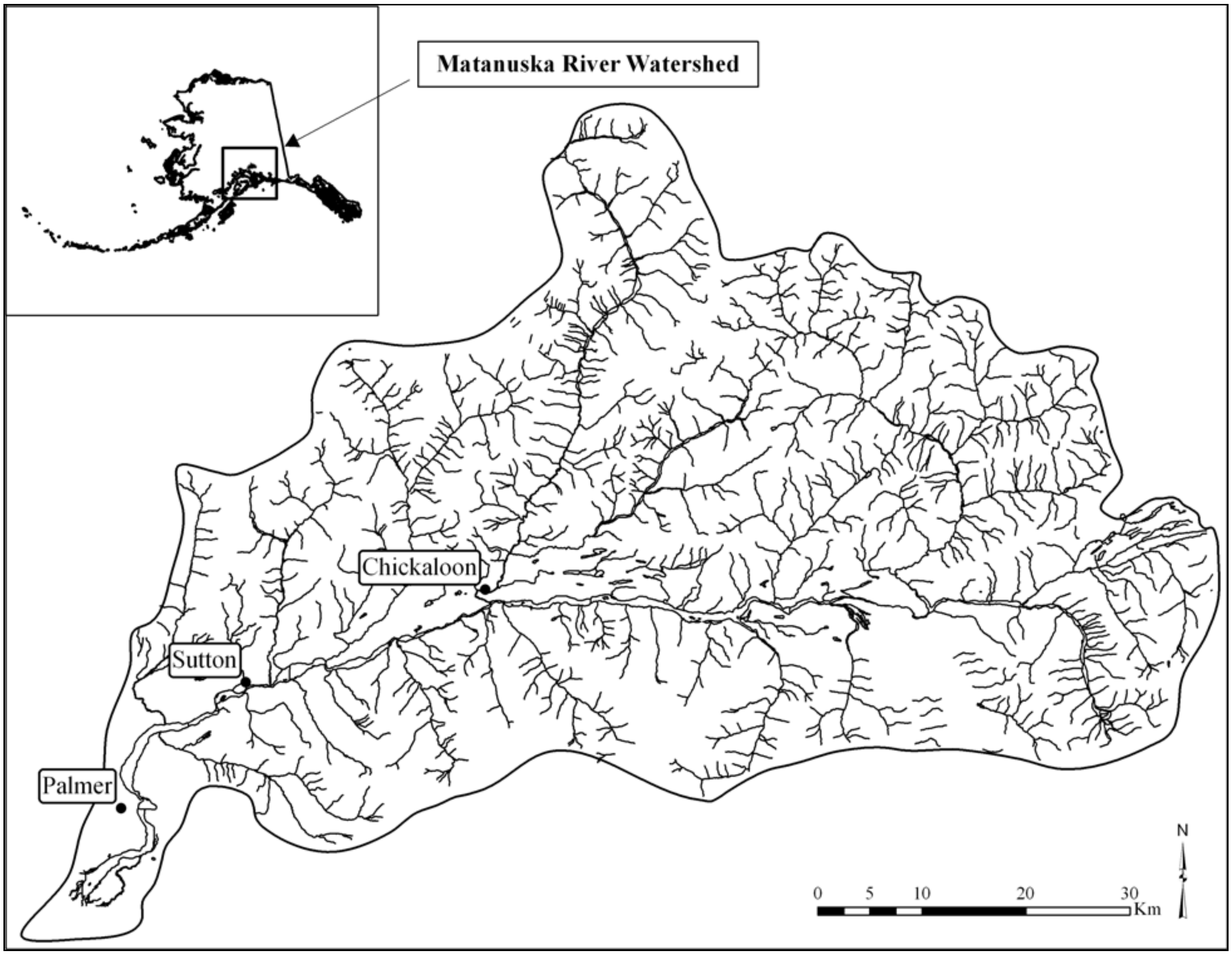

Figure 1. Matanuska River watershed, southcentral Alaska.

survival and growth of salmonids (Lloyd et al. 1987). The Matanuska River carries tremendous amounts of sediment creating high turbidity, with mid-summer peak flows regularly exceeding 30,000 ft^3/s (U. S. Geological Survey (USGS) gage data). Although the main channels of glacial rivers may be too swift and unstable to provide much fish habitat, off-channel and side channel habitats can provide important spawning and rearing habitat for salmonids in glacial rivers (Roth et al. 1984; Lorenz and Eiler 1989; Murphy et al. 1989; Eiler et al. 1992). Recent work on the Matanuska River indicates that juvenile salmonids utilize clearwater side channels for rearing habitat and side channels are thought to provide much of the available spawning habitat for Pacific salmon in the Matanuska River watershed (USGS and Chickaloon Native Village, unpublished data).

Five species of Pacific salmon spawn and rear in the Matanuska River and its tributaries. The Alaska Department of Fish and Game (ADF&G) has documented Chinook *O. tshawytscha* and sockeye salmon in the mainstem Matanuska River and four tributary streams; coho salmon in 13 tributary streams and the mainstem Matanuska River; chum salmon in the mainstem river and six tributary streams; and pink salmon *O. gorbuscha* in the mainstem Matanuska River (Table 1). These distribution data are thought to be incomplete, and little is known about the abundance of any of these species.

Table 1. Distribution of Pacific salmon species in the Matanuska River watershed based on data reported in the Johnson and Weiss (2007). p = present; s = spawning; r = rearing.

	Salmon Species				
Waterbody	Chinook	Coho	Chum	Sockeye	Pink
Upper Matanuska River	p	p	s	s	
Caribou Creek			s		
Coal Creek		s			
Tatondan Lake & outlet stream		p		s	
Chickaloon River		r	s		
Lower Matanuska River	p	p, s	p, s	p, s	p
Carbon Creek		s			
Carptenter Creek		s			
Kings River	s	p, s, r	s		
Granite Creek	s	s	s		
Little Granite Creek & tributary		r	s	s, r	
Eska Creek		p	s		
Stream 1220-2098 & trib		s			
Wolverine Lake & outlet trib		s, r		p, s	
Wolverine Creek	p	s		p	
Moose Creek	s	s			

Methods

We operated a live capture fishwheel on the Matanuska River at a constricted site above the bridge on the Old Glenn Highway at river km 19. The initial site was chosen based on accessibility and professional judgment following several site visits by ADF&G personnel and other experts. The fishwheel was designed and constructed by ADF&G and consisted of two 7.3 m long aluminum floats connected by two 3.7 m long aluminum catwalks and a four-spoke, height-adjustable rotating axle (Figure 2). The overall radius of the basket assembly was 2.3 m and we connected two 2.3 m deep by 1.8 m wide baskets and two 2.3 by 1.8 m paddle frames to the axle. The maximum effective fishing radius of the basket assembly was 1.5 m based on the height of the axle above the water. We adjusted the basket assembly to fish as near to the stream bottom as possible to maximize capture efficiency and moved the axle and the fishwheel as necessary to optimize water flow and depth. We attempted to maintain a basket rotation speed between 2 and 3.5 rpm. Captured fish were passed from the basket via an aluminum slide mechanism into a 0.6 m wide by 2.4 m long by 1.2 m deep plywood live box that was perforated with holes and slits on the sides and bottom to allow water circulation and to prevent sediment build up.

We initially operated the fishwheel to maximize effort each day, including several overnight fishing periods. Our goal as the season progressed was to operate the fishwheel from 4 to 6 hours per day to meet telemetry sample size goals and monitor run timing. The live box was checked throughout the period of operation, usually about once per hour to minimize effects of capture and handling that can lead to increased mortality and changes in migration timing (Bromaghin et al. 2007). Captured fish were netted from the live box and either included in the radio telemetry sample or released. All fish captured at the fishwheel were identified to species and counted. Catch data were recorded at each sampling interval and catch per unit effort (CPUE, fish per hour) was calculated for each sampling period and summarized for each day.

Salmon that were part of the radio telemetry sample were netted from the live box and handled in the water in a padded cradle. Fish length was measured to the nearest mm (mid-eye to fork of tail) and the sex of the fish was determined from external characteristics when possible. Three scales from each sockeye and coho salmon and one scale from each chum salmon were removed from the preferred area on the left side (Jearld 1983), cleaned, and mounted on gummed scale cards. The axillary process was removed with clippers and placed in alcohol for genetic analysis by ADF&G. Radio transmitters developed by Advanced Telemetry Systems, Inc. (ATS) were gastrically implanted through the esophagus using a plunger as described by Burger et al. (1985) and were immediately released into the river. Total handling time for each tagged fish was about one minute. All efforts were made to minimize stress during capture and handling.

Scales were pressed and aged following the field season by U. S. Fish and Wildlife Service (USFWS) personnel. Standards and guidelines of Mosher (1968) were used in aging scales and salmon ages are reported according to the European method described by Jearld (1983) and Mosher (1968) where the number of winters the fish spent in fresh water and in the ocean are separated by a decimal. Age, sex, and length characteristics of chum, coho, and sockeye salmon were summarized for the entire season.

Radio transmitters (ATS Model No. F1845B) were encapsulated in a biologically inert polypropylene copolymer and weighed 26 g which never exceeded 2% of the fish's body weight (Winter 1983). Transmitters measured 56 mm in length with a diameter of 19 mm and each had a 346-mm stainless steel nylon coated whip antenna. Three hundred unique pulse-coded tags

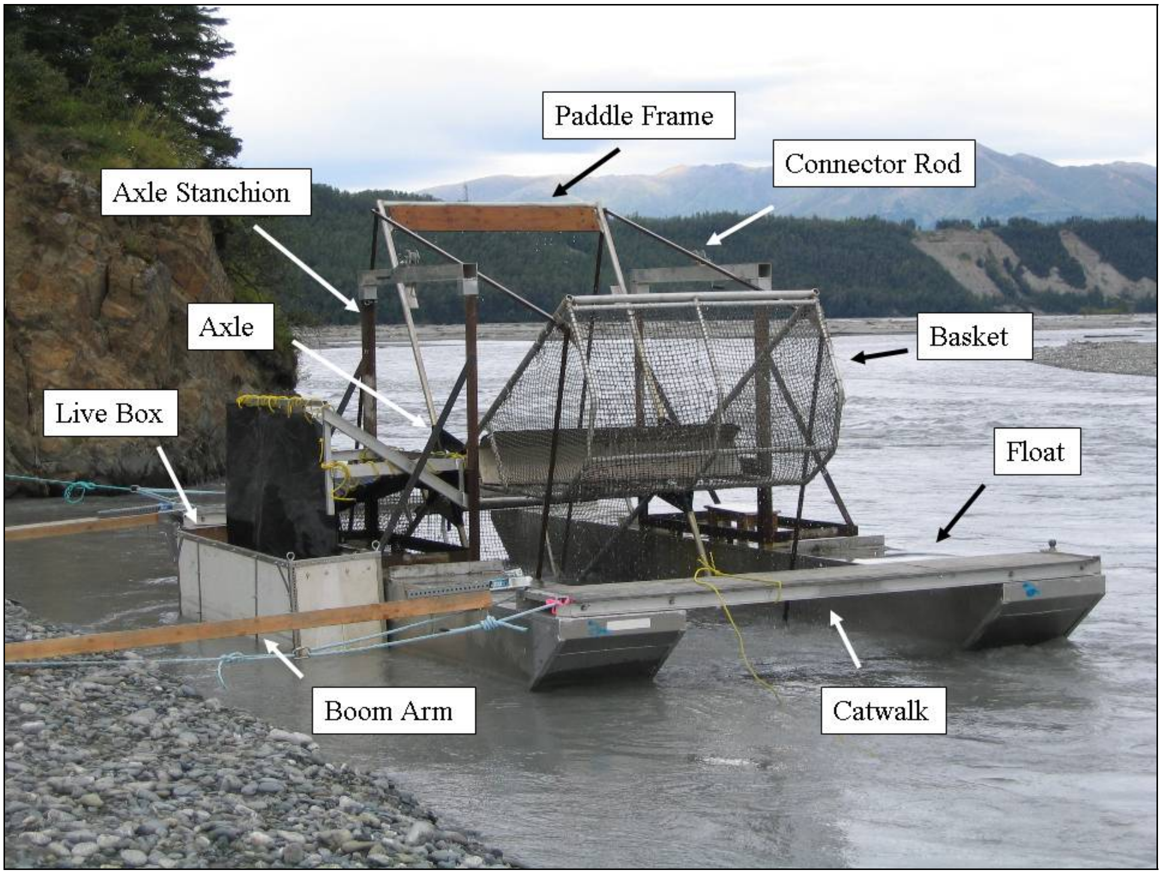

Figure 2. Fishwheel used on the Matanuska River, 2008.

were used and were distributed equally over 7 frequencies between 164 and 165 MHz with a minimum 20 KHz separation between frequencies. The combination of codes on each frequency allowed the identification of unique tags (fish) and a mortality code was activated after 8 hours of inactivity.

In order to calculate sample sizes, we assumed that capture and tagging of salmon does not cause them to change their ultimate spawning locations, fish destined for the various spawning locations have an equal probability of capture within each stratum, and tagged fish behave independently. Under these assumptions, the binomial probability distribution (Johnson et al. 1992) provides a useful model for the number of fish to be observed at a particular spawning location for each species. Using a binomial model, 19 tagged fish minimally satisfied the criteria of Objectives 3-5, so 20 radio transmitters were allocated to each stratum. However, we adjusted the tagging strata as the season progressed to reflect effort and catch (Table 2).

Radio transmitters were deployed in as short of a time period as possible within each stratum. This was the most efficient deployment strategy given our limited knowledge of the abundance and run timing of salmon in the Matanuska River and our unknown ability to capture salmon with a fishwheel at this location. Tagging fish as quickly as we could capture them increased the likelihood that all tags were deployed within each stratum. If the target number of tags could not be deployed within a particular stratum, we attempted to deploy remaining tags in the subsequent

Table 2. Sampling strata (time frames) for distribution of chum, coho, and sockeye salmon radio transmitters, 2008.

	Strata Dates		Transmitters	
Stratum	Preseason	Adjusted	Allocated	Deployed
	Chum Salmon			
1	1 – 10 July	27 July – 2 Aug	20	1
2	11 – 20 July	3 – 9 Aug	20	12
3	21 – 30 July	10 – 16 Aug	20	20
4	31 July – 14 Aug	17 – 25 Aug	20	20
5	15 – 31 Aug	26 Aug – 4 Sept	10	10
	Coho Salmon			
1	15 July – 15 Aug	27 July – 2 Aug	20	17
2	16 – 25 Aug	3 – 9 Aug	40	34
3	26 Aug – 4 Sept	10 – 16 Aug	40	40
4	5 – 14 Sept	17 – 25 Aug	20	20
5	15 Sept – 15 Oct	26 Aug – 4 Sept	20	20
6	--	5 – 30 Sept	20	15
	Sockeye Salmon			
1	1 – 10 July	27 July – 2 Aug	20	20
2	11 – 20 July	3 – 9 Aug	20	15
3	21 – 30 July	10 – 16 Aug	20	20
4	31 July – 14 Aug	17 – 25 Aug	20	20
5	15 – 31 Aug	26 Aug – 4 Sept	10	10

strata. Although pulse sampling admits the possibility that the tagged fish are not fully representative of all fish passing during an entire stratum, any resulting bias was expected to be small and did not compromise our ability to achieve the objectives of this investigation.

Radio-tagged salmon were tracked throughout the Matanuska River watershed using fixed receiver sites and mobile surveys. Radio telemetry receivers and data logging computers manufactured by ATS were used for all mobile and fixed station tracking. Fixed receiver stations were used to automatically identify and record fish movements. Three stations were established on the mainstem Matanuska River; one was located about 7 km above the fishwheel capture site, one was located near Sutton, and one was located below the mouth of the Chickaloon River. An additional station was established on the Chickaloon River. Fixed receiver stations included either a single data logging receiver or a separate receiver and data logging computer, a 4-element Yagi antenna, antenna mast, 12 V deep cycle battery, solar panel, voltage regulator, and strongbox. Receivers were programmed to scan through all frequencies at 4-s intervals. Data from fixed receiver stations were downloaded weekly to a notebook computer.

Mobile surveys were used to identify specific spawning locations in the Matanuska River watershed. Aerial surveys were conducted from late August through November from a Piper Supercub fixed-wing aircraft equipped with two H-antennas, one mounted on each wing strut. Aerial surveys were conducted approximately 150 to 200 m above ground along the Matanuska River and tributary watersheds. A global positioning system (GPS) built in to the datalogging receiver was used during all aerial surveys to record latitude and longitude coordinates for each transmitter. Ground-based tracking followed aerial surveys and helped refine spawning areas and was conducted from locations accessed by rafts, highway vehicles, and on foot. During ground-based mobile surveys, a portable receiver and 4-element Yagi antenna were used and the receiver was allowed to scan through all transmitter frequencies for at least 4 s on each frequency while sweeping the antenna back and forth in an arc covering the search area. The transmitter frequency-code combination, location, gain setting, and other comments were recorded on pre-printed forms.

Each radio-tagged salmon was assigned one of seven possible fates based on information collected from mobile and fixed radio receivers (Table 3). The collection of tagged fish known to enter the study area, any water upstream of river km 19, constituted the sample for purposes of estimating spawning distributions. Fish assigned a fate of harvested or dead/regurgitated were censored from the sample. Fish whose spawning location could not be determined with reasonable certainty were placed into an unknown category.

Spawning locations were defined based on the tracking results. A tagged fish that migrated to a particular location and remained in the area for an extended period of time without activating the mortality sensor was considered to have identified a potential spawning location. An area in which two or more fish were detected was considered to be a confirmed spawning location for purposes of this investigation.

The hypothesis that the distribution of spawners was identical among all tagging strata was tested using Fisher's exact chi-square tests, as implemented in the R function Fisher test (RCDT 2008, version 2.8.1). Significance levels (p-values) were estimated using 100,000 bootstrap re-samples.

Table 3. Fates assigned to radio transmitters for analysis purposes.

Fate	Description
Lower Watershed Spawner	A fish that spawns in the Matanuska River or its tributaries between river km 19 and river km 35.
Middle Watershed Spawner	A fish that spawns in the Matanuska River or its tributaries between river km 37 and river km 71.
Upper Watershed Spawner	A fish that spawns in the Matanuska River or its tributaries between river km 77 and river km 100.
Dead/Regurgitated	A fish that did not complete its spawning migration because it either died or regurgitated its radio transmitter.
Harvested	A fish harvested in the sport fishery.
Back Out	A fish that has dropped out of the Matanuska River watershed
Unknown	A fish that has a loss of contact with mobile or fixed radio receivers or cannot be assigned another fate with reasonable certainty.

Stream flow (discharge, ft^3/s) was monitored by a USGS gaging station at the bridge on the Old Glenn Highway (gage number 15284000). The gage reports staff height and discharge and historic data are available since 1949.

Results

We operated a live capture fishwheel at river km 19 on the Matanuska River for 206.3 hours on the river left bank from 22 July to 14 August and for 161.4 hours from 15 August to 22 September on the river right bank. The fishwheel was moved across the river in response to lateral changes of the river channel. A total of 194 chum, 461 coho, and 350 sockeye salmon were captured between 27 July and 18 September with 50^{th} percentile passage dates of 19 August for chum and coho salmon and 17 August for sockeye salmon (Table 4, Figure 3, Appendix A). Other fish captured included Chinook salmon (n = 3), Dolly Varden *Salvelinus malma* (n = 13), round whitefish *Prosopium cylindraceum* (n = 7), and longnose sucker *Catostomus catostomus* (n = 1). Peak fishwheel catches occurred on 18 August for all species (Figure 4, Appendix A). Catch rates and numbers were greater at the river right bank fishwheel location (Table 4). We also fished a dipnet for 18.75 hours between 22 July and 9 August and captured one chum, one coho, eight sockeye, and two pink salmon.

Mean daily stream discharge peaked at 14,000 ft^3/s on 29 July and was generally lower than historic values (Figure 5). Stream discharge generally decreased as the season progressed and no direct correlation between fishwheel CPUE and discharge was apparent (Figure 6). However, decreasing stream discharge in September was partially responsible for our low catch rates.

Fixed receiver stations were operated from 30 July through 17 October and were downloaded nine times during the course of the study. Sixteen ground searches were conducted between 25 August and 22 October and seven aerial searches were conducted between 28 August and 25 November.

Table 4. Summary of 2008 fishwheel catch data by fishwheel location (river left or river right). Minimum catch per hour values for all species were zero.

		Catch per hour		
Species	Catch	Mean	Maximum	Standard Deviation
		River Left (22 July – 14 August)		
Chum salmon	30	0.21	1.38	0.34
Coho salmon	92	0.50	1.47	0.45
Sockeye salmon	119	0.64	2.83	0.77
Total	241	1.35	4.33	1.21
		River Right (15 August – 22 September)		
Chum salmon	164	0.98	4.93	1.38
Coho salmon	369	2.25	15.43	3.39
Sockeye salmon	231	1.41	9.86	2.22
Total	763	4.64	30.21	6.74
		Overall		
Chum salmon	194	0.69	4.93	1.16
Coho salmon	461	1.58	15.43	2.79
Sockeye salmon	350	1.11	9.86	1.83
Total	1,005	3.38	30.21	5.55

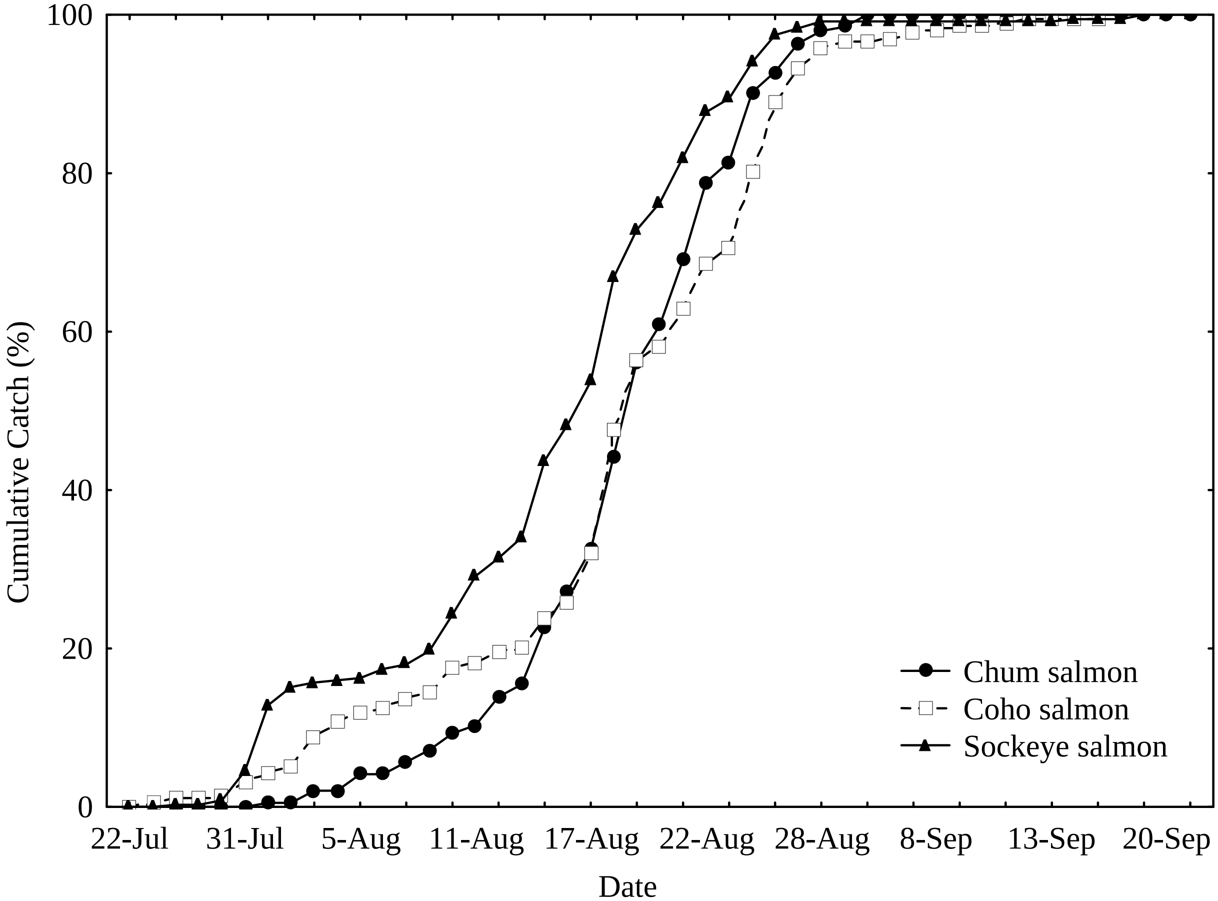

Figure 3. Cumulative catch of chum, coho, and sockeye salmon at the Matanuska River fishwheel, 2008.

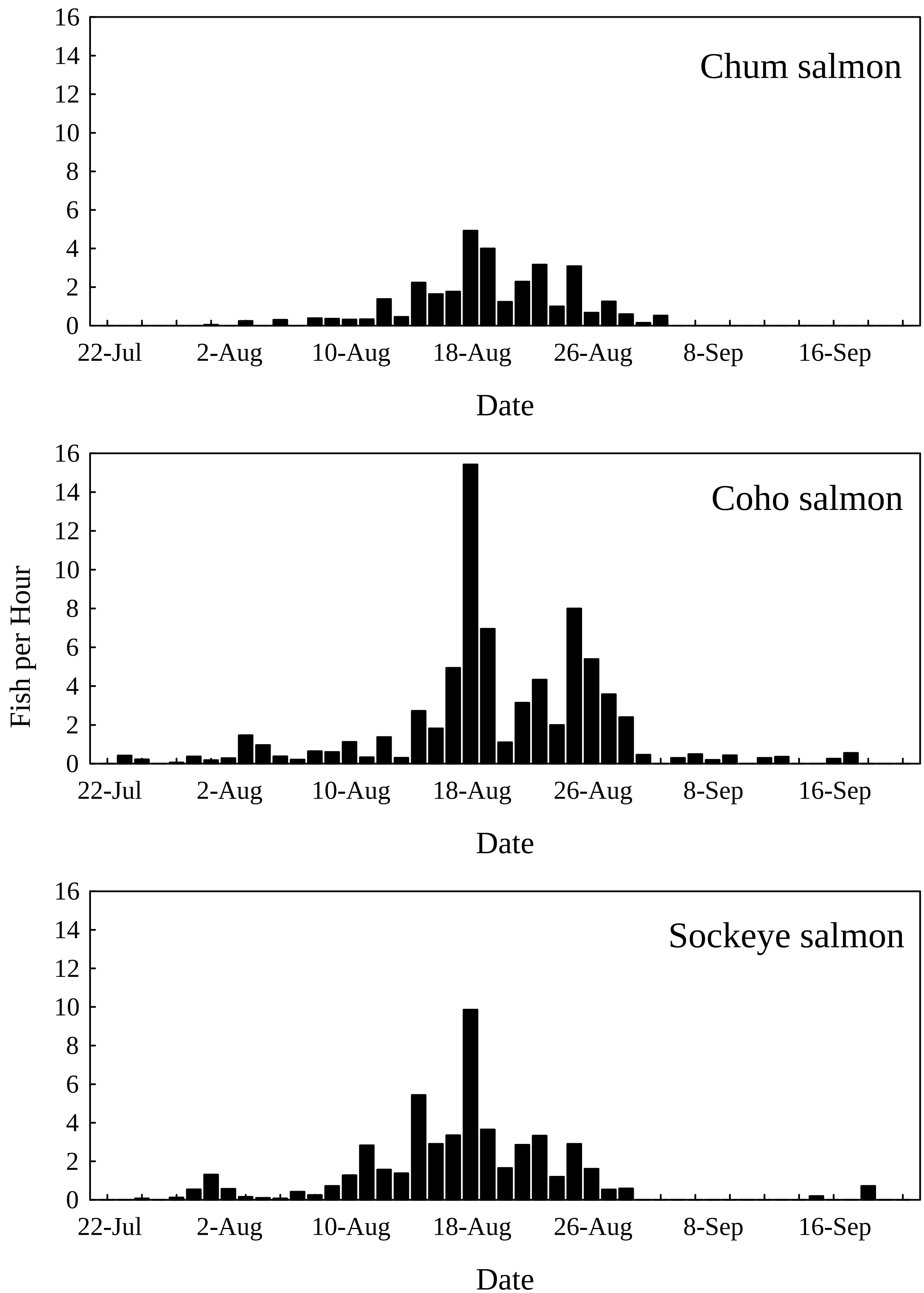

Figure 4. Catch per effort for chum, coho, and sockeye salmon expressed as the number of fish captured per hour at the Matanuska River fishwheel, 2008.

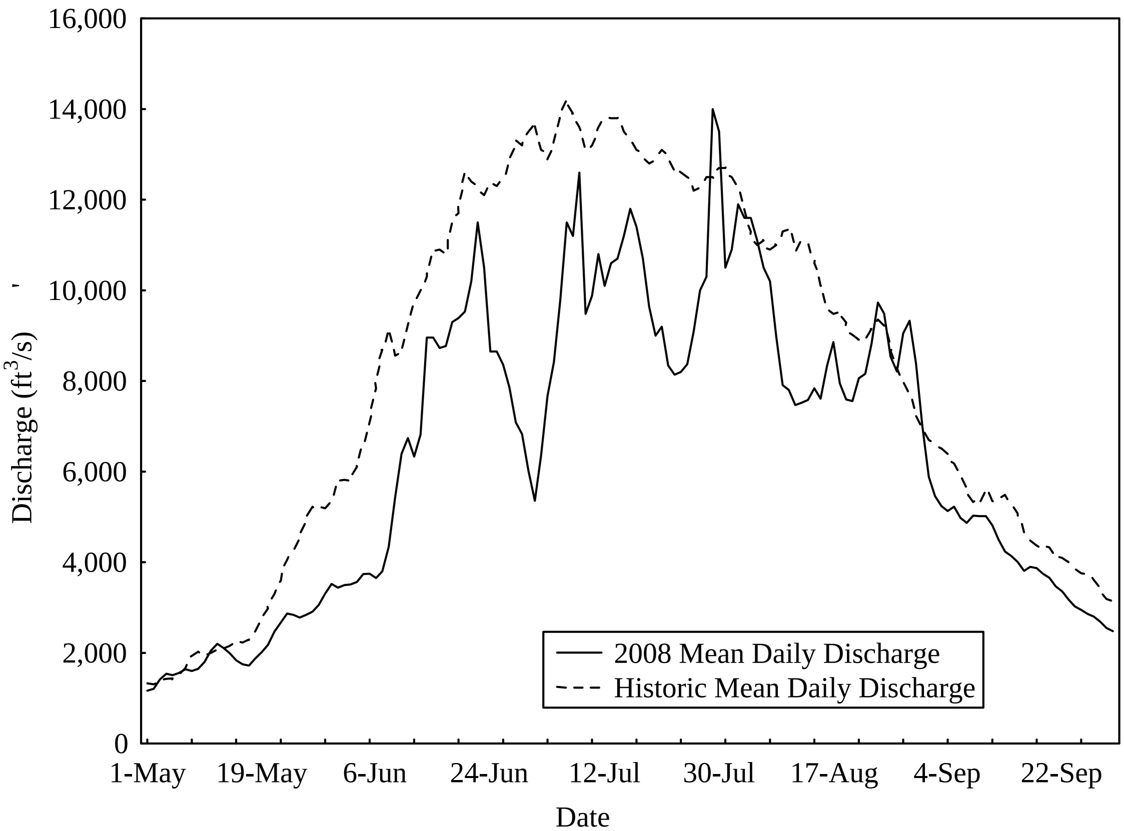

Figure 5. Summary of mean daily discharge on the Matanuska River near Palmer, Alaska, 2008 and historic (1949 to 2007), USGS gage number 15284000.

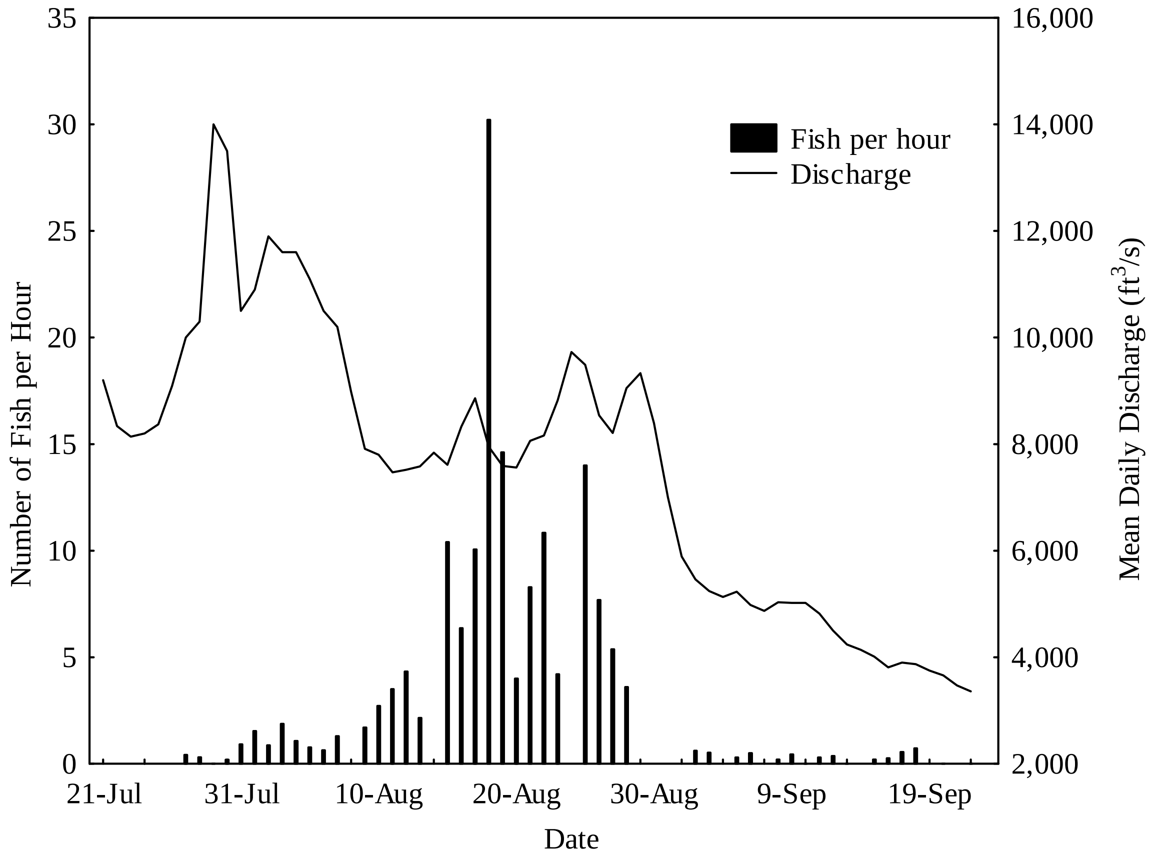

Figure 6. Plot of mean daily discharge and fishwheel catch per effort on the Matanuska River, 2008.

Fisher's exact chi-square procedure was used to test the hypothesis that the distribution of spawners was equal among all temporal tagging strata for each species. We did not catch many chum salmon initially and caught more coho salmon than expected, so we increased coho salmon sample size goals to use the extra transmitters. Two-hundred sixty-three fish were successfully tracked to spawning areas, 17 fish backed out of the study area, and 14 fish were not successfully tracked to a spawning location (Tables 5 and 6, Figure 7, Appendix B). Over 90% of chum (n = 42) and 98% of sockeye salmon (n = 81) selected spawning locations in mainstem areas of the Matanuska River while 56% of coho salmon (n = 75) selected spawning locations in tributaries, primarily the Tatondan Lake (n = 45) and Wolverine Creek (n = 25) watersheds. Most radio-tagged coho salmon that selected the Tatondan Lake watershed were found in the tributary stream that feeds the lake.

An exact chi-square procedure was used to test the hypothesis that the distribution of spawners was equal among all temporal tagging strata for each species. Fish were classified into three categories for this test: lower, middle, and upper watershed spawners (Table 6). The test was significant for coho salmon (P = 0.003) indicating that the distribution of spawners was not equal among all tagging strata. The significance of the test was primarily due to the lack of middle and upper watershed spawners after stratum 5 (Table 7). The test was not significant for chum (P = 0.83) or sockeye salmon (P = 0.22).

Age, sex, and length data were collected from 64 chum salmon from 1 to 27 August, 153 coho salmon from 29 July to 17 September, and 104 sockeye salmon from 28 July to 28 August. Scales could not be collected from five coho (3%), 31 sockeye (30%), and all but four chum salmon (94%). Scales were starting to reabsorb on most chum and some sockeye salmon. Scale samples were unreadable or regenerated for 21 coho (14%) and nine sockeye salmon (12%). Sex could not be determined from external characteristics for two chum, 11 coho, and five sockeye salmon. Length was not measured on one chum and two sockeye salmon.

Three age classes were identified from four chum salmon scale samples in 2008: ages 0.2 (n = 2), 0.3 (n = 1), and 0.4 (n = 1). Forty-seven percent of the chum salmon sampled at the fishwheel were female (Table 8). Lengths of chum salmon sampled in 2008 ranged from 490 to 638 mm for females and from 541 to 643 mm for males (Table 9, Figure 8).

Three age classes were identified from coho salmon scale samples in 2008. Age 2.1 fish made up the majority of the run (83%, Table 10). Fifty-one percent of coho salmon sampled at the fishwheel were female (Table 8). Lengths of coho salmon sampled in 2008 ranged from 502 to 617 mm for females and from 456 to 632 mm for males (Table 11, Figure 8).

Six age classes were identified from sockeye salmon scale samples in 2008. Most fish sampled were age 1.2 (61%, Table 12). Fifty-two percent of the sockeye salmon sampled at the fishwheel were female (Table 8). Lengths of sockeye salmon sampled in 2008 ranged from 448 to 606 mm for females and from 440 to 612 mm for males (Table 13, Figure 8).

Table 5. Number (percentage in parentheses) of transmitters for each salmon species assigned to fate categories.

Fate	Chum	Coho	Sockeye	All Salmon
Lower Watershed Spawner	42 (67)	59 (40)	39 (46)	140 (48)
Middle Watershed Spawner	4 (6)	28 (19)	35 (41)	67 (23)
Upper Watershed Spawner	--	48 (33)	8 (9)	56 (19)
Dead/Regurgitated	--	--	--	--
Harvested	--	--	--	--
Back Out	11 (17)	4 (3)	2 (2)	17 (6)
Unknown	6 (10)	7 (5)	1 (1)	14 (5)
Total	63	146	85	294

Table 6. Spawning location aggregations of chum, coho, and sockeye salmon identified based on number of radio transmitters, 2008.

Spawning Location	Chum	Coho	Sockeye	Total	River km
Lower Watershed					
Bartko Side Channel Complex	12	12	15	39	19[a]
Palmer Area	1	3	2	6	21 to 24
Moose Creek Watershed	3	3	0	6	31[a]
Wolverine Creek Watershed	0	25	1	26	31[a]
Moose/Wolverine Confluence Area	26	16	21	63	26 to 35
Middle Watershed					
Eska Creek Side Channel Complex	2	4	17	23	37 to 42
Granite Creek Watershed	1	2	0	3	45[a]
Above Granite Creek	0	6	7	13	43 to 50
Above Kings River	1	9	4	14	50 to 56
Pinnacle Mountain Area	0	5	7	12	56 to 64
Below Chickaloon River	0	2	0	2	64 to 71
Upper Watershed					
Riley Creek Side Channel Complex	0	2	5	7	77 to 80
Long Lake Side Channel Complex	0	0	2	2	82 to 85
Ninemile Creek to Gravel Creek	0	1	1	2	85 to 98
Tatondan Lake Watershed	0	45	0	45	100[a]
Total	46	135	82	263	

[a] Distance to mouth of tributary stream or side channel.

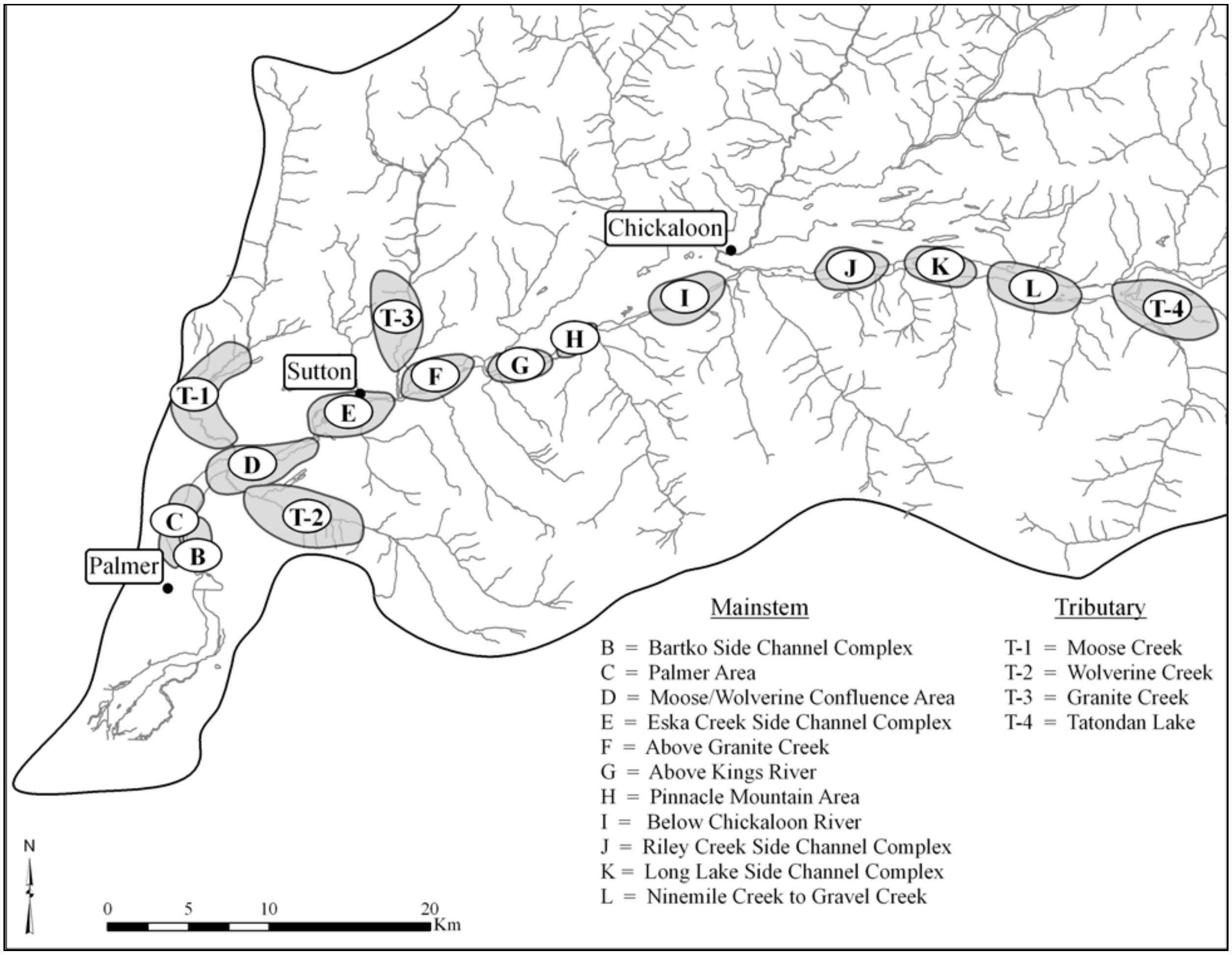

Figure 7. Spawning aggregations identified in the Matanuska River watershed, 2008.

Table 7. Numbers of chum, coho, and sockeye salmon summarized by spawning location in the watershed and tagging stratum, 2008. Spawning locations are detailed in Table 6.

	Spawning Location		
Tagging Stratum	Lower Watershed	Middle Watershed	Upper Watershed
		Chum salmon	
1	1	0	0
2	10	2	0
3	13	1	0
4	11	1	0
5	7	0	0
		Coho salmon	
1	5	5	6
2	8	7	16
3	16	7	13
4	11	3	6
5	6	6	7
6	13	0	0
		Sockeye salmon	
1	6	10	4
2	6	5	2
3	8	10	2
4	12	8	0
5	7	2	0

Table 8. Sex composition of chum, coho, and sockeye salmon sampled at the Matanuska River fishwheel, 2008.

Sex	*n*	%	SE (%)
		Chum salmon	
Female	29	47	6.4
Male	33	53	6.4
Total	62		
		Coho salmon	
Female	69	51	4.3
Male	67	49	4.3
Total	136		
		Sockeye salmon	
Female	51	52	5.0
Male	48	48	5.0
Total	99		

Table 9. Mean length (mm), SE, range, and sample size by sex for chum salmon sampled at the Matanuska River fishwheel, 2008.

	Female	Male
Mean	587	593
SE	30	27
Minimum	490	541
Maximum	638	643
n	28	33

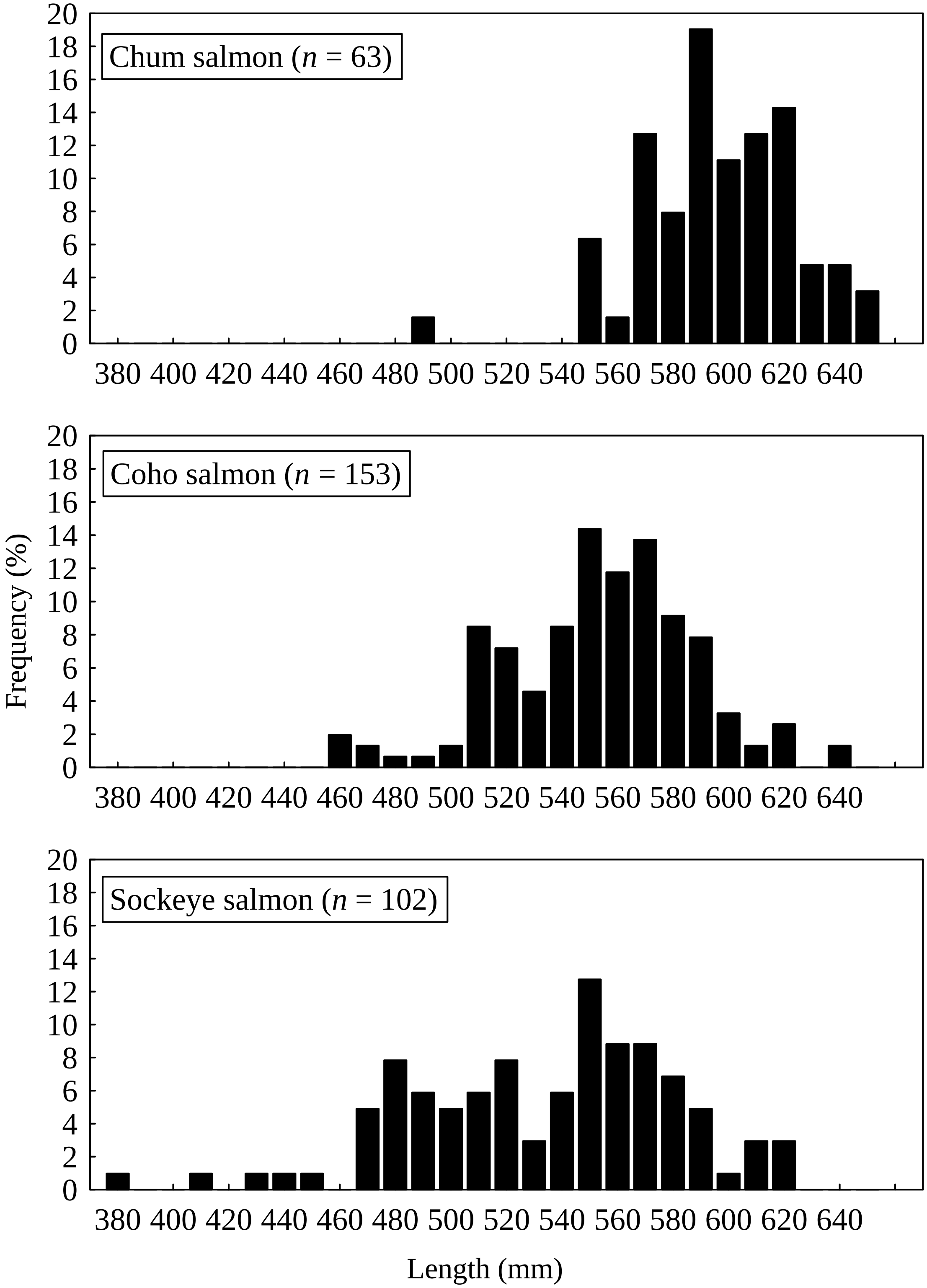

Figure 8. Length frequency distribution of chum, coho, and sockeye salmon sampled at the Matanuska River fishwheel, 2008.

Table 10. Age composition of coho salmon sampled at the Matanuska River fishwheel, 2008.

Age	*n*	%	SE (%)
1.1	17	13	3.1
2.1	104	83	3.4
3.1	5	4	1.7
Total	126		

Table 11. Mean length (mm), SE, range, and sample size by sex and age taken from coho salmon at the Matanuska River fishwheel, 2008.

	Age		
	1.1	2.1	3.1
Female			
Mean	557	557	519
SE	41	23	7
Minimum	502	502	512
Maximum	617	597	526
n	8	47	3
Male			
Mean	517	541	573
SE	51	38	30
Minimum	456	468	551
Maximum	580	632	594
n	8	48	2
Total			
Mean	538	548	540
SE	48	33	34
Minimum	456	456	512
Maximum	617	632	594
n	17	104	5

Table 12. Age composition of sockeye salmon sampled at the Matanuska River fishwheel, 2008.

Age	*n*	%	SE (%)
0.3	1	2	1.6
1.2	39	61	6.1
1.3	9	14	4.4
1.5	1	2	1.6
2.2	8	13	4.2
2.3	6	9	3.7
Total	64		

Table 13. Mean length (mm), SE, range, and sample size by sex and age taken from sockeye salmon at the Matanuska River fishwheel, 2008.

	Age					
	0.3	1.2	1.3	1.5	2.2	2.3
			Female			
Mean	--	515	553	--	491	548
SE	--	42	30	--	23	16
Minimum	542	448	505	--	466	525
Maximum	--	603	606	--	519	563
n	1	21	8	--	5	4
			Male			
Mean	--	535	--	--	492	--
SE	--	50	--	--	34	--
Minimum	--	440	--	--	463	573
Maximum	--	612	--	--	529	--
n	--	18	--	--	3	1
			Total			
Mean	--	524	536	--	492	563
SE	--	46	56	--	25	30
Minimum	542	440	406	537	463	525
Maximum	--	612	606	--	529	615
n	1	39	9	1	8	6

Discussion

We were successful in operating a fishwheel to capture migrating salmon on the Matanuska River in 2008, but we do not know how effective we were in describing the early run timing of chum and sockeye salmon or the late run timing of coho salmon. Several factors influenced our catch rates throughout the season. The first fish captured at the fishwheel in late July were coho salmon, so we believe that we were able to describe the early run timing for that species. Our observed run timing for sockeye salmon on the Matanuska River was considerably later by about four weeks compared to the Yentna River and Fish Creek in upper Cook Inlet (Table 14). Run timing for coho salmon observed at our capture site was similar to the Little Susitna River but considerably later than the Deshka River (Table 14). No escapement project in upper Cook Inlet reported chum salmon run timing in 2008.

We were unable to get our fishwheel on-site and ready to fish until 21 July and water levels were too low to fish effectively until 27 July. During the period from 21 to 27 July, we sampled likely holding areas (i.e., deep pools and eddies) with a dip net for almost 17 hours and did not catch, encounter, or observe any salmon. Therefore, it is unlikely that large numbers of salmon were present in the Matanuska River near our sampling area before we were able to sample effectively with a fishwheel. Fish may have been holding in the lower river and started migrating upriver with increasing stream discharge beginning on 26 July, the same pulse of water that allowed us to sample effectively with the fishwheel (Figure 6).

Once the river discharge increased starting on 26 July we were able to fish effectively until about 6 August. After 6 August, water levels dropped and the fishwheel would not spin faster than 1.25 rpm. The fishwheel also stopped spinning on an intermittent basis, so we began to manually turn the wheel when necessary beginning on 7 August. We attempted to move the fishwheel to new locations on the river left bank with little success. The fishwheel did not spin faster than 2 rpm from 7 August to 13 August and on 14 August we moved the fishwheel to the river right bank. The fishwheel sampled effectively on the river right bank until flows dropped considerably in early September (Figure 6). The fishwheel did not spin effectively from 2 to 22 September and catch rates were low. The low catch rates observed late in the season were likely a combination of poor fishwheel location and efficiency due to low stream discharge, and low relative abundance of salmon in the system.

A combination of changing stream discharge and changes in streambed morphology (i.e., shifting substrate and sediment deposition) affected the fishwheel efficiency on both river banks, but we were able to compensate on most days by adjusting the axle height or fishwheel position. However, conditions on both banks deteriorated over time to the point that we could no longer fish effectively. We were also limited in safe alternatives to place the fishwheel. It was not safe to move the wheel from one side of the river to the other and channel morphology on either bank ultimately limited effective fishing locations.

Catch rates for all species increased dramatically after the fishwheel was moved to the river right bank on 14 August (Table 4, Figure 4). We suspect the river right bank provided a better location to intercept migrating salmon, although our movement of the fishwheel could have coincided with an increase in relative abundance of all species in the Matanuska River. There was no apparent difference in spawning distribution based on bank of capture, but any test of bank orientation is confounded with run timing (Table 4). It is unlikely that the upriver spawning distribution of salmon in the Matanuska River was related to bank of capture since the

Table 14. Summary of 50th percentile passage dates observed for chum, coho, and sockeye salmon in northern Cook Inlet watersheds, 2008.

Watershed	Method	Chum	Coho	Sockeye
Matanuska River	Fishwheel	19 Aug	19 Aug	17 Aug
Deshka River[a]	Weir	--	30 July	--
Little Susitna River[a]	Weir	--	29 Aug	--
Fish Creek[a]	Weir	--	--	25 July
Yentna River[a]	Sonar	--	--	20 July

[a] Alaska Department of Fish and Game, unpublished data.

main channel of the river is less than 100 m wide at either of our fishwheel capture sites in 2008, and the two capture locations on either bank were fishing the same confined channel.

Most chum salmon selected mainstem spawning areas lower in the watershed than coho or sockeye salmon. The farthest upriver we observed radio-tagged chum salmon was the side channel complex above the Kings River at river km 56. However, Johnson and Weiss (2007) document chum salmon spawning in lower Caribou Creek which joins the Matanuska River at river km 121. It is possible that chum salmon spawned in Caribou Creek and other areas of the Matanuska River watershed where we did not observe radio-tagged fish. These could be fish that passed our capture site before the fishwheel was operational, fish that passed the capture site during times when we were experiencing low capture efficiencies, or fish spawning in areas that do not constitute major spawning aggregations. Increasing the radio transmitter sample size would improve our probability of detecting some of these small aggregations.

The distribution of radio-tagged coho salmon was similar among mainstem and tributary spawning areas in 2008, although slightly more (56%) selected tributary systems. More radio-tagged coho salmon selected the Tatondan Lake and Wolverine Creek watersheds than any other area (Table 6). Johnson and Weiss (2007) document coho salmon spawning in several tributary streams that we did not classify as spawning aggregations in 2008. However, we did not target our search effort in these smaller tributaries. The documented anadromous reaches for Coal, Carbon, and Carpenter creeks occupy the lower 2 to 4 km of those streams, so radio transmitters (if present) in those streams were probably detected while surveying the mainstem Matanuska River.

We observed differential run timing for coho salmon in 2008. None of the coho salmon that we implanted with radio transmitters in September selected spawning areas in the middle or upper Matanuska River watershed (Table 7). Palmer et al. (2008) observed similar differences in run timing for coho salmon in the Kasilof River watershed in southcentral Alaska. Fish that spawned higher in the watershed (tributaries to Tustumena Lake) were tagged at their capture site earlier than fish that spawned in the mainstem river. Coho salmon that migrate early tend to move further upstream in a watershed than fish that migrate later (Sandercock 1991).

Nearly all sockeye salmon selected spawning areas on the mainstem Matanuska River braid plain and most (65%) selected spawning sites in three primary areas, the Bartko (18%) and Eska Creek (21%) side channel complexes and the Moose Creek/Wolverine Creek mouth area (26%) of the mainstem braid plain (Table 6, Figure 7). We expected to find more sockeye salmon associated with the Wolverine and Tatondan lake watersheds as documented by Johnson and Weiss (2007; Table 1), but fish destined for these lake systems may have passed our capture site early in the year before the fishwheel was operational, during times when we were experiencing low capture efficiencies, or may represent small spawning aggregations compared to the mainstem braid plain. As with chum salmon, increasing our radio transmitter sample size would improve our probability of detecting some of these small aggregations.

Although previous work documented sockeye salmon spawning in clearwater side channels of the mainstem Matanuska River (USGS, unpublished data), the extent they are used compared to tributary habitat was enlightening. Most sockeye salmon typically spawn in systems with associated lake rearing habitat where the juveniles feed on zooplankton before smolting and migrating to the ocean to complete their life cycle, although populations spawning in riverine habitats without associated lake systems have been documented (Burgner 1991). Juvenile sockeye salmon in some systems without associated lakes do not overwinter in freshwater and migrate to the ocean as age 0 fish (Foerster 1968; Wood et al. 1987; Lorenz and Eiler 1989; Burgner 1991). These fish have been termed sea-type sockeye salmon by Wood et al. (1987). Eiler et al. (1992) found over 60% of sockeye salmon in the Taku River watershed, a large glacial river in southeast Alaska, spawned in river areas without access to lake habitat and most of these exhibited the sea-type life history. In other river systems where juvenile sockeye salmon do not have access to lakes, fry overwinter in spring areas, side channels, and sloughs (Burgner 1991). In the Stikine River, a large glacial river in southeast Alaska, the lower mainstem channel margins and slack-water habitat provide important rearing habitat for juvenile sockeye salmon produced in tributary or mainstem river areas without access to lake habitats (Wood et al. 1987). Most of these were river-type sockeye that spent one winter in freshwater before migrating to the ocean (age 1.X). Similar river-type life histories for sockeye salmon have been documented in areas of the Kamchatka River without access to lake habitat (Bugaev 1987).

Scale age analysis indicates that most adult sockeye captured and radio-tagged at the fishwheel had spent at least one winter in freshwater as juveniles and most coho salmon had spent two winters in fresh water. These fish probably find suitable rearing habitat in the clearwater side channels or other off-channel habitats in the mainstem Matanuska River braid plain, or in or near tributary mouths. The lower mainstem and associated off-channel rearing areas of the Taku River provide important rearing habitat for juvenile sockeye, coho, and Chinook salmon (Murphy et al. 1989; Murphy et al. 1997). Important rearing habitat types identified for juvenile salmon include main channel braids and sloughs, beaver ponds, tributary mouths, and upland sloughs (Murphy et al. 1989). These habitat types in the lower river also provided important overwintering habitat for juvenile coho and Chinook salmon (Murphy et al. 1997). Roth et al. (1984) found that side channels and sloughs of the mainstem Susitna River, a large glacial river in southcentral Alaska, provided important spawning and rearing habitat for sockeye salmon in areas with no access to lake habitat. Dugan et al. (1984) also identified important rearing habitats for juvenile salmon in the Susitna River. Side sloughs and upland sloughs were important rearing areas for sockeye, side sloughs and tributaries were important for chum, mainstem side channels were important for Chinook, and tributaries and upland sloughs were important rearing habitat for coho salmon.

Although we were able to describe the spawning distribution of Pacific salmon in the Matanuska River above river km 19, numerous clearwater side channels below our fishwheel probably provide spawning habitat for a large number of salmon. Most spawning observed on the mainstem Matanuska River above the fishwheel was associated with clearwater side channels and the USGS has identified and mapped more of this habitat below our fishwheel site (72 km) than above it (56 km; USGS unpublished data). Not all clearwater side channel habitat provides suitable spawning habitat for salmon, but it is likely that more spawning habitat is available for salmon below our capture site than above it.

We did not spend enough time tracking fish on the ground to verify the exact spawning locations of all fish. Our aerial searches were very effective at locating transmitters throughout the watershed at the scale of the spawning aggregation delineated in Figure 5, but we were not effective in identifying exact spawning locations within those aggregations from the air. The goal of most of our ground searches was also to locate as many transmitters as possible within a given search area and usually focused on large sections of the watershed. We were able to identify exact locations of some fish in clearwater side channels and some transmitters recovered in carcasses, but this required easy access and considerable effort. Therefore, we are still unable to estimate the proportion of fish that spawn in clearwater side channels compared to fish that spawn in turbid waters of the mainstem braid plain. Salmon spawning in glacially turbid habitats has been documented by many researchers (Burger et al. 1985; Lorenz and Eiler 1989; Barton 1992; Eiler et al. 1992; Burger et al. 1995; Savereide 2003; Young and Woody 2007). We suspect that fish spawn in the glacially turbid habitats of the Matanuska River, but we need to spend more time tracking fish to exact spawning locations to verify this assumption.

We did not observe any radio-tagged fish in the Chickaloon or Kings river watersheds or some of the other smaller tributary streams documented by Johnson and Weiss (2007; Table 1). As mentioned previously, fish destined for these watersheds may have passed the fishwheel early in the season before we were able to sample, passed the fishwheel during times when we were experiencing low capture efficiencies, or may represent small spawning aggregates. Increasing our radio transmitter sample size would improve our probability of detecting some of these small aggregations. Some tributary spawning could have occurred that we did not document because fish could have entered the systems, spawned, and dropped back down to the mainstem river between our surveys.

We were unable to collect scale samples from some sockeye salmon (n = 31, 30%) and most chum salmon (n = 60, 94%) in 2008 because the scales had begun to reabsorb and were not easy to grasp with tweezers and remove from the fish. Our priority was to sample and release fish as quickly as possible to minimize handling effects, so we did not prolong our attempts to remove scales. However, we were unable to describe the age composition of radio-tagged chum salmon in 2008 because we did not collect enough scale samples.

Based on the spawning distributions and the conditions at numerous clearwater side channels observed in 2008, it appears feasible to conduct a mark-recapture estimate of spawning abundance. Using the fishwheel as our capture and marking platform, all salmon could be differentially marked over time (Wydoski and Emery 1983). Carcasses could be examined for marks while conducting spawning ground surveys on selected clearwater side channels. Spawning abundance of sockeye, chum, and coho salmon could be estimated using a stratified Petersen estimator (Darroch 1961).

Recommendations

Based on results of the 2008 field season, we make the following recommendations for future years:

- Two fishwheels should be operated if possible, one on each river bank. This would allow fish to be sampled more effectively throughout the season as the thalweg moves from one side of the channel to the other.
- The fishwheels should be in position and ready to sample by mid June so that the early run timing for all species can be described.
- The datalogger site on the Chickaloon River should be discontinued in future years because no radio-tagged fish migrated past it in 2008. The datalogger could be moved elsewhere in the watershed or could be used on other projects.
- More effort should be dedicated to ground tracking to determine if fish are spawning in any of the glacially turbid channels. Specific effort should focus on the mainstem braid plain near the Moose Creek/Wolverine Creek mouths area.
- Temperature data loggers should be deployed on each fishwheel in future years to correlate catch rates with water temperature.
- Walking surveys should be conducted in some of the clearwater side channel complexes below the fishwheel to document relative abundance of spawners and/or carcasses compared to what is observed in the clearwater side channels above the capture site. This could provide a rough estimate of the magnitude of run size when compared with an abundance estimate for fish spawning above the capture site.
- The importance of the mainstem Matanuska River braid plain for fish production should be taken into consideration when assessing current and future development activities.

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References

Apodaca, C. K., and D. W. Daum. 2006. Estimated abundance of adult fall chum salmon in the middle Yukon River, Alaska, 2005 – Final Report. U.S. Fish and Wildlife Service, Fairbanks Fish and Wildlife Field Office, Alaska Fisheries Technical Report Number 89, Fairbanks, Alaska.

Barton, L. H. 1992. Tanana River, Alaska, fall chum salmon radio telemetry study. Alaska Department of Fish and Game, Fishery Research Bulletin 92-01, Anchorage, Alaska.

Bromaghin, J. F., T. J. Underwood, and R. F. Hander. 2007. Residual effects from fish wheel capture and handling of Yukon River fall chum salmon. North American Journal of Fisheries Management 27:860-872.

Bugaev, V. F. 1987. Scale patterns and biology of juvenile sockeye salmon (*Oncorhynchus nerka*) in the Kamchatka River. Pages 36-43 *in* H. D. Smith, L. Margolis, and C. C. Wood, editors. Sockeye salmon (*Oncorhynchus nerka*) population biology and future management. Canadian Special Publication of Fisheries and Aquatic Sciences 96.

Burger, C. V., J. E. Finn, and L. Holland-Bartels. 1995. Patterns of shoreline spawning by sockeye salmon in a glacially turbid lake: evidence for population differentiation. Transactions of the American Fisheries Society 124:1-15.

Burger, C. V., R. L. Wilmot, and D. B. Wangaard. 1985. Comparison of spawning areas and times for two runs of Chinook salmon *Oncorhynchus tshawytscha* in the Kenai River, Alaska. Canadian Journal of Fisheries and Aquatic Sciences 42: 693-700.

Burgner, R. L. 1991. Life history of sockeye salmon (*Oncorhynchus nerka*). Pages2-117 *in* C. Groot and L. Margolis, editors. Pacific salmon life histories. University of British Columbia Press, Vancouver, British Columbia.

Cleary, P. M., and T. Hamazaki. 2007. Fall chum salmon mark-recapture abundance estimation on the Tanana and Kantishna rivers, 2007. Alaska Department of Fish and Game, Fishery Data Series Number 07-45, Anchorage, Alaska.

Darroch, J. N. 1961. The two-sample capture-recapture census when tagging and sampling are stratified. Biometrika 48:241-260.

Dugan, L. J., D. A. Sterritt, and M. E. Stratton. 1984. The distribution and relative abundance of juvenile salmon in the Susitna River drainage above the Chulitna River confluence. 984 Report No. 2, Part 2, Alaska Department of Fish and Game, Susitna Hydro Aquatic Studies, Anchorage, Alaska.

Eiler, J. H., B. D. Nelson, and R. F. Bradshaw. 1992. Riverine spawning by sockeye salmon in the Taku River, Alaska and British Columbia. Transactions of the American Fisheries Society 121:701-708.

Foerster, R. E. 1968. The sockeye salmon, *Oncorhynchus nerka*. Bulletin of the Fisheries Research Board of Canada 162, Nanaimo, British Columbia.

Fox, J., and P. Shields. 2005. Upper Cook Inlet commercial fisheries annual management report, 2004. Alaska Department of Fish and Game, Report to the Board of Fisheries, 2005, Anchorage.

Jearld, A. 1983. Age determination. Pages 301-324 *in* L. A. Nielsen and D. L. Johnson, editors. Fisheries Techniques. American Fisheries Society, Bethesda, MD.

Johnson, J., and E. Weiss. 2007. Catalog of waters important for spawning, rearing, or migration of anadromous fishes – Southcentral Region, Effective June 1, 2007. Alaska Department of Fish and Game, Special Publication No. 07-05, Anchorage, Alaska.

Johnson, N. L., S. Kotz, and N. Balakrishnan. 1992. Univariate discrete distributions. John Wiley & Sons, New York, New York.

Link, M. R., and K. K. English. 1996. The 1993 fishwheel project on the Nass River and an evaluation of fishwheels as an inseason management and stock assessment tool for the Nass River. Canadian Technical Report of Fisheries and Aquatic Sciences 2130.

Link, M. R., and K. K. English. 2000. Long-term sustainable monitoring of Pacific salmon populations using fishwheels to integrate harvesting, management, and research. Pages 667 to 674 *in* E. E. Knudsen, C. R. Steward, D. D. MacDonald, J. E. Williams, and D. W. Reiser, editors. Sustainable fisheries management: Pacific salmon. Lewis Publications, Boca Raton, Florida.

Lloyd, D. S., Koenings, J. P., and J. D. La Perriere. 1987. Effects of turbidity in fresh waters of Alaska. North American Journal of Fisheries Management 7:18-33.

Lorenz, J. M., and J. H. Eiler. 1989. Spawning habitat and redd characteristics of sockeye salmon in the glacial Taku River, British Columbia and Alaska. Transactions of the American Fisheries Society 118:495-502.

MSBSHP (Mat-Su Basin Salmon Habitat Partnership). 2008. Conserving salmon in the Mat-Su basin: The Strategic Action Plan of the Mat-Su Basin Salmon Habitat Partnership. Available: http://conserveonline.org/workspaces/MatSuSalmon

Milner, A. M., and G. E. Petts. 1994. Glacial rivers: physical habitat and ecology. Freshwater Biology 32:295-307.

Mosher, K. H. 1968. Photographic atlas of sockeye salmon scales. Fishery Bulletin 67:243-280.

Murphy, M. L., J. Heifetz, J. F. Thedinga, S. W. Johnson, and K. V. Koski. 1989. Habitat utilization by juvenile Pacific salmon (*Oncorhynchus*) in the glacial Taku River, southeast Alaska. Canadian Journal of Fisheries and Aquatic Sciences 46:1677-1685.

Murphy, M. L., K. V. Koski, J. M. Lorenz, and J. F. Thedinga. 1997. Downstream migrations of juvenile Pacific salmon (*Oncorhynchus* spp.) in a glacial transboundary river. Canadian Journal of Fisheries and Aquatic Sciences 54:2837-2846.

Palmer, D. E., K. S. Gates, and J. F. Bromaghin. 2008. Run timing, abundance, and distribution of adult coho salmon in the Kasilof River watershed, Alaska, 2007. U.S. Fish and Wildlife Service, Alaska Fisheries Data Series Report Number 2008-19, Kenai, Alaska.

Pawluk, J., J. Baumer, T. Hamazaki, and D. Orabutt. 2006. A mark-recapture study of Kuskokwim River Chinook, sockeye, chum and coho salmon, 2005. Alaska Department of Fish and Game, Fishery Data Series Number 06-54, Anchorage, Alaska.

RDCT (R Development Core Team). 2008. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org.

Roth, K. J., D. C. Gray, and D. C. Schmidt. 1984. The outmigration of juvenile salmon from the Susitna River above the Chulitna River confluence. 1984 Report No. 2, Part 1, Alaska Department of Fish and Game, Susitna Hydro Aquatic Studies, Anchorage, Alaska.

Sandercock, F. K. 1991. Life history of coho salmon (*Oncorhynchus kisutch*). Pages 395-446 *in* C. Groot and L. Margolis, editors. Pacific salmon life histories. University of British Columbia Press, Vancouver, British Columbia.

Savereide, J. W. 2003. Inriver abundance, spawning distribution, and run timing of Copper River Chinook salmon, 2002–2004. Alaska Department of Fish and Game, Fishery Data Series Number 05-50, Anchorage, Alaska.

Savereide, J. W. 2005. Inriver abundance, spawning distribution, and run timing of Copper River Chinook salmon in 2002. Alaska Department of Fish and Game, Fishery Data Series Number 03-21, Anchorage, Alaska.

Sweet, D., S. Ivey, and D. Rutz. 2003. Area management report for the recreational fisheries of Northern Cook Inlet, 2001 and 2002. Alaska Department of Fish and Game, Fishery Management Report No. 03-10, Anchorage, Alaska.

U. S. Census Bureau. 2001. Counties ranked by percent population change: 1990 to 2000. Census 2000 Gateway, Population Distribution Branch. Available: http://www.census.gov/population/www/cen2000/phc-t4.html.

Vincent-Lang, D., and D. McBride. 1989. Stock origins of coho salmon in the commercial harvests from Upper Cook Inlet, Alaska. Alaska Department of Fish and Game, Fishery Data Series Number 93, Anchorage.

Wade, G. D., K. M. van den Broek, J. W. Savereide, and J. J. Smith. 2007. Spawning distribution and run timing of Copper River sockeye salmon, 2006 annual report. U.S. Fish and Wildlife Service, Office of Subsistence Management, Fisheries Resource Monitoring Program (Study No. 05-501), Anchorage, Alaska.

Willette, T. M., R. DeCino, and N. Gove. 2003. Mark-recapture population estimates of coho, pink, and chum salmon runs to upper Cook Inlet in 2002. Alaska Department of Fish and Game, Regional Information Report 2A03-20, Anchorage, Alaska.

Winter, J. D. 1983. Underwater Biotelemetry. Pages 371-395 *in* L. A. Nielsen and D. L. Johnson, editors. Fisheries Techniques. American Fisheries Society, Bethesda, MD.

Wood, C. C., B. E. Riddell, and D. T. Rutherford. 1987. Alternative life histories of sockeye salmon (*Oncorhynchus nerka*) and their contribution to production in the Stikine River, northern British Columbia. Pages 12-24 *in* H. D. Smith, L. Margolis, and C. C. Wood, editors. Sockeye salmon (*Oncorhynchus nerka*) population biology and future management. Canadian Special Publication of Fisheries and Aquatic Sciences 96.

Wydoski, R., and L. Emery. 1983. Tagging and marking. Pages 215-237 *in* L. A. Nielsen and D. L. Johnson, editors. Fisheries Techniques. American Fisheries Society, Bethesda, MD.

Yanusz, R., R. Merizon, D. Evans, M. Willette, T. Spencer, and S. Raborn. 2007. Inriver abundance and distribution of spawning Sustina River sockeye salmon *Oncorhynchus nerka*. Alaska Department of Fish and Game, Fishery Data Series No. 07-83, Anchorage, Alaska.

Young, D. B., and C. A. Woody. 2007. Spawning distribution of sockeye salmon in a glacially influenced watershed: the importance of glacial habitats. Transactions of the American Fisheries Society 136:452-459.

Appendix A. Daily summary of fishwheel effort and catch for chum, coho, and sockeye salmon in the Matanuska River, 2008.

Date	Effort (h)	Chum salmon	Coho salmon	Sockeye salmon
22-Jul	2.0	0	0	0
27-Jul	4.8	0	2	0
28-Jul	13.3	0	3	1
29-Jul	20.6	0	0	0
30-Jul	15.7	0	1	2
31-Jul	24.0	0	9	13
1-Aug	22.1	1	4	29
2-Aug	13.8	0	4	8
3-Aug	12.3	3	18	2
4-Aug	9.3	0	9	1
5-Aug	13.0	4	5	1
6-Aug	9.4	0	2	4
7-Aug	7.8	3	5	2
9-Aug	8.3	3	5	6
10-Aug	12.5	4	14	16
11-Aug	6.0	2	2	17
12-Aug	5.1	7	7	8
13-Aug	6.5	3	2	9
15-Aug	6.3	14	17	34
16-Aug	5.5	9	10	16
17-Aug	5.7	10	28	19
18-Aug	4.7	23	72	46
19-Aug	5.8	23	40	21
20-Aug	7.3	9	8	12
21-Aug	7.0	16	22	20
22-Aug	6.0	19	26	20
23-Aug	5.0	5	10	6
25-Aug	5.5	17	44	16
26-Aug	7.4	5	40	12
27-Aug	5.6	7	20	3
28-Aug	5.0	3	12	3
2-Sep	6.5	1	3	0
3-Sep	5.8	3	0	0
5-Sep	6.7	0	2	0
6-Sep	8.1	0	4	0
8-Sep	5.0	0	1	0
9-Sep	4.6	0	2	0
10-Sep	4.9	0	0	0
11-Sep	6.7	0	2	0
12-Sep	5.5	0	2	0
13-Sep	7.5	0	0	0

-continued-

Appendix A. continued.

Date	Effort (h)	Chum salmon	Coho salmon	Sockeye salmon
15-Sep	5.0	0	0	1
16-Sep	3.8	0	1	0
17-Sep	3.6	0	2	0
18-Sep	2.8	0	0	2
20-Sep	4.5	0	0	0
22-Sep	4.0	0	0	0
Total:	367.7	194	460	350

Appendix B. Summary of biological data and tracking history for chum, coho, and sockeye salmon radio-tagged in the Matanuska River, 2008.

Fish ID	Species	Sex	Length (mm)	Age	Tag Date	Tag Stratum	Spawning Location	Watershed Fate	Number of Detections
1	Sockeye	F	549	1.3	17-Aug	4	Eska Mouth Complex	Middle	10
2	Chum	M	543	--	17-Aug	4	Moose/Wolverine Mouths	Lower	15
3	Chum	F	620	--	17-Aug	4	Moose/Wolverine Mouths	Lower	16
4	Coho	M	555	UR	17-Aug	4	Tatondan Lake	Upper	9
5	Coho	F	565	2.1	29-Jul	1	Tatondan Lake	Upper	12
6	Coho	F	545	2.1	17-Aug	4	Wolverine	Lower	10
7	Chum	F	556	--	17-Aug	4	Moose/Wolverine Mouths	Lower	8
8	Chum	F	611	--	12-Aug	3	Bartko	Lower	8
9	Coho	M	569	2.1	17-Aug	4	Moose/Wolverine Mouths	Lower	12
10	Sockeye	F	484	1.2	30-Jul	1	Above Kings River Mouth	Middle	11
11	Coho	M	580	1.1	31-Jul	1	Wolverine	Lower	11
12	Coho	F	560	UR	30-Jul	1	Moose/Wolverine Mouths	Lower	7
13	Coho	M	507	2.1	17-Aug	4	Wolverine	Lower	9
14	Coho	U	535	2.1	17-Aug	4	Wolverine	Lower	6
15	Coho	M	506	2.1	17-Aug	4	Above Granite Mouth	Middle	16
16	Sockeye	M	474	1.2	31-Jul	1	Riley Mouth	Upper	11
17	Coho	M	575	1.1	17-Aug	4	Above Kings River Mouth	Middle	11
18	Coho	U	614	2.1	16-Aug	3	Wolverine	Lower	14
19	Chum	M	588	--	17-Aug	4	Unknown	Unknown	0
20	Coho	M	504	2.1	15-Aug	3	Tatondan Lake	Upper	13
21	Coho	F	518	3.1	15-Aug	3	Wolverine	Lower	11
22	Coho	F	586	2.1	26-Aug	5	Tatondan Lake	Upper	10
23	Coho	F	564	UR	15-Aug	3	Moose/Wolverine Mouths	Lower	15
24	Coho	F	555	1.1	12-Aug	3	Tatondan Lake	Upper	13
25	Coho	M	589	UR	17-Sep	6	Moose Creek	Lower	8
26	Coho	M	555	1.1	6-Sep	6	Palmer	Lower	3
27	Sockeye	U	552	--	18-Aug	4	Moose/Wolverine Mouths	Lower	16
29	Coho	M	503	2.1	26-Aug	5	Above Kings River Mouth	Middle	9
30	Coho	M	562	UR	26-Aug	5	Granite Creek Watershed	Middle	12
32	Sockeye	M	511	--	18-Aug	4	Eska Mouth Complex	Middle	7
33	Chum	F	583	--	12-Aug	3	Palmer	Lower	11
34	Coho	F	601	UR	12-Aug	3	Wolverine	Lower	8
35	Chum	F	582	--	27-Aug	5	Bartko	Lower	11
36	Chum	F	566	--	26-Aug	5	Moose/Wolverine Mouths	Lower	8
37	Coho	M	564	--	16-Sep	6	Bartko	Lower	5
38	Coho	M	564	2.1	16-Aug	3	Wolverine	Lower	14
39	Chum	F	545	--	12-Aug	3	Below Glenn Highway	Back Out	2
40	Coho	M	536	2.1	26-Aug	5	Above Granite Mouth	Middle	14

-continued-

Appendix B. continued.

Fish ID	Species	Sex	Length (mm)	Age	Tag Date	Tag Stratum	Spawning Location	Watershed Fate	Number of Detections
41	Coho	U	560	2.1	26-Aug	5	Tatondan Lake	Upper	8
42	Chum	M	605	--	18-Aug	4	Moose/Wolverine Mouths	Lower	10
43	Sockeye	M	509	--	17-Aug	4	Bartko	Lower	4
44	Coho	F	559	2.1	17-Aug	4	Wolverine	Lower	5
45	Sockeye	M	573	--	17-Aug	4	Wolverine	Lower	4
46	Coho	M	551	3.1	17-Aug	4	Tatondan Lake	Upper	8
47	Sockeye	M	517	--	1-Aug	1	Bartko	Lower	5
48	Chum	F	606	--	17-Aug	4	Moose/Wolverine Mouths	Lower	14
49	Coho	M	531	2.1	17-Aug	4	Tatondan Lake	Upper	9
50	Coho	M	576	2.1	17-Aug	4	Moose/Wolverine Mouths	Lower	16
51	Coho	M	592	UR	26-Aug	5	Tatondan Lake	Upper	9
52	Coho	F	549	2.1	17-Aug	4	Moose/Wolverine Mouths	Lower	6
53	Coho	F	510	2.1	31-Jul	1	Tatondan Lake	Upper	8
54	Coho	F	615	UR	1-Aug	1	Above Kings River Mouth	Middle	9
55	Coho	M	544	UR	17-Aug	4	Wolverine	Lower	11
56	Sockeye	F	570	1.3	3-Aug	2	Below Glenn Highway	Back Out	6
57	Coho	M	594	3.1	16-Aug	3	Granite Creek Watershed	Middle	9
58	Coho	M	502	2.1	31-Jul	1	Tatondan Lake	Upper	9
59	Sockeye	F	563	2.3	17-Aug	4	Bartko	Lower	6
60	Coho	M	579	2.1	17-Aug	4	Moose/Wolverine Mouths	Lower	13
61	Sockeye	M	569	--	17-Aug	4	Eska Mouth Complex	Middle	7
62	Chum	M	592	--	17-Aug	4	Unknown	Unknown	0
63	Coho	F	502	2.1	26-Aug	5	Tatondan Lake	Upper	6
64	Sockeye	M	484	2.2	1-Aug	1	Above Granite Mouth	Middle	10
65	Sockeye	M	567	1.2	18-Aug	4	Bartko	Lower	14
66	Chum	M	634	--	18-Aug	4	Below Glenn Highway	Back Out	6
67	Sockeye	F	547	1.3	18-Aug	4	Moose/Wolverine Mouths	Lower	8
68	Coho	U	537	2.1	15-Aug	3	Bartko	Lower	7
69	Sockeye	M	545	--	17-Aug	4	Moose/Wolverine Mouths	Lower	10
70	Sockeye	F	542	0.3	26-Aug	5	Moose/Wolverine Mouths	Lower	13
71	Coho	M	569	2.1	26-Aug	5	Unknown	Unknown	0
72	Coho	U	593	UR	26-Aug	5	Bartko	Lower	7
73	Sockeye	F	537	UR	18-Aug	4	Eska Mouth Complex	Middle	10
74	Chum	U	602	--	17-Aug	4	Moose/Wolverine Mouths	Lower	14
75	Coho	F	544	UR	17-Aug	4	Above Granite Mouth	Middle	9
76	Coho	M	509	2.1	26-Aug	5	Pinnacle Mountain Area	Middle	7
77	Sockeye	F	603	1.2	26-Aug	5	Bartko	Lower	6
78	Chum	M	643	--	12-Aug	3	Moose/Wolverine Mouths	Lower	16
79	Coho	M	632	2.1	26-Aug	5	Wolverine	Lower	9

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Appendix B. continued.

Fish ID	Species	Sex	Length (mm)	Age	Tag Date	Tag Stratum	Spawning Location	Watershed Fate	Number of Detections
80	Coho	F	544	2.1	15-Aug	3	Moose/Wolverine Mouths	Lower	12
81	Chum	M	567	--	15-Aug	3	Eska Mouth Complex	Middle	11
82	Sockeye	M	574	1.2	17-Aug	4	Bartko	Lower	5
83	Coho	F	536	2.1	26-Aug	5	Bartko	Lower	6
84	Coho	F	548	1.1	16-Aug	3	Tatondan Lake	Upper	11
85	Coho	M	562	2.1	15-Aug	3	Tatondan Lake	Upper	9
86	Coho	F	576	2.1	17-Aug	4	Tatondan Lake	Upper	10
87	Coho	F	572	2.1	10-Aug	3	Wolverine	Lower	12
88	Chum	M	618	--	10-Aug	3	Moose/Wolverine Mouths	Lower	11
89	Coho	F	563	2.1	13-Aug	3	Moose/Wolverine Mouths	Lower	13
90	Chum	M	582	--	3-Aug	2	Moose/Wolverine Mouths	Lower	7
91	Coho	F	579	2.1	11-Aug	3	Pinnacle Mountain Area	Middle	8
92	Coho	F	510	2.1	2-Aug	1	Tatondan Lake	Upper	11
93	Chum	M	601	--	1-Aug	1	Moose Creek	Lower	4
94	Coho	F	556	2.1	5-Aug	2	Palmer	Lower	13
95	Sockeye	M	535	1.2	10-Aug	3	Riley Mouth	Upper	10
96	Coho	M	584	2.1	10-Aug	3	Unknown	Unknown	2
97	Chum	F	605	--	10-Aug	3	Below Glenn Highway	Back Out	7
98	Sockeye	F	480	UR	10-Aug	3	Moose/Wolverine Mouths	Lower	17
99	Coho	M	556	UR	2-Aug	1	Wolverine	Lower	12
100	Sockeye	M	612	1.2	1-Aug	1	Eska Mouth Complex	Middle	16
101	Sockeye	F	558	1.2	11-Aug	3	Eska Mouth Complex	Middle	14
102	Coho	M	538	2.1	10-Aug	3	Bartko	Lower	9
103	Sockeye	F	507	1.2	9-Aug	2	Eska Mouth Complex	Middle	17
104	Sockeye	M	542	1.2	1-Aug	1	Above Kings River Mouth	Middle	9
105	Coho	M	560	2.1	16-Aug	3	Tatondan Lake	Upper	6
106	Coho	F	547	2.1	2-Aug	1	Eska Mouth Complex	Middle	12
107	Coho	M	532	2.1	15-Aug	3	Unknown	Unknown	0
108	Chum	M	570	--	5-Aug	2	Moose/Wolverine Mouths	Lower	19
109	Sockeye	M	504	--	9-Aug	2	Bartko	Lower	11
110	Sockeye	F	550	UR	31-Jul	1	Pinnacle Mountain Area	Middle	10
111	Sockeye	M	558	--	9-Aug	2	Bartko	Lower	4
112	Sockeye	M	498	--	9-Aug	2	Below Glenn Highway	Back Out	4
113	Chum	M	614	--	5-Aug	2	Above Kings River Mouth	Middle	14
114	Coho	M	471	2.1	3-Aug	2	Tatondan Lake	Upper	8
115	Chum	M	587	--	9-Aug	2	Bartko	Lower	11
116	Chum	M	598	--	9-Aug	2	Bartko	Lower	9
117	Coho	M	631	2.1	5-Aug	2	Tatondan Lake	Upper	8
118	Sockeye	M	573	2.3	6-Aug	2	Eska Mouth Complex	Middle	10

-continued-

Appendix B. continued.

Fish ID	Species	Sex	Length (mm)	Age	Tag Date	Tag Stratum	Spawning Location	Watershed Fate	Number of Detections
119	Coho	F	526	3.1	5-Aug	2	Wolverine	Lower	8
120	Coho	M	547	2.1	3-Aug	2	Tatondan Lake	Upper	8
121	Sockeye	U	537	1.5	1-Aug	1	Above Kings River Mouth	Middle	13
122	Chum	M	541	--	9-Aug	2	Moose/Wolverine Mouths	Lower	15
123	Coho	F	530	2.1	5-Aug	2	Moose/Wolverine Mouths	Lower	13
124	Sockeye	M	546	--	5-Aug	2	Bartko	Lower	7
125	Coho	M	550	2.1	6-Aug	2	Above Granite Mouth	Middle	14
126	Coho	M	495	2.1	31-Jul	1	Wolverine	Lower	14
127	Coho	F	559	2.1	4-Aug	2	Ninemile to Gravel	Upper	7
128	Sockeye	M	589	--	7-Aug	2	Eska Mouth Complex	Middle	10
129	Coho	f	515	1.1	9-Aug	2	Bartko	Lower	6
130	Coho	M	563	2.1	3-Aug	2	Tatondan Lake	Upper	11
131	Coho	M	523	2.1	3-Aug	2	Tatondan Lake	Upper	9
132	Sockeye	M	463	2.2	1-Aug	1	Moose/Wolverine Mouths	Lower	13
133	Coho	F	570	2.1	7-Aug	2	Tatondan Lake	Upper	14
134	Coho	F	590	2.1	1-Aug	1	Tatondan Lake	Upper	12
135	Sockeye	M	558	1.2	4-Aug	2	Palmer	Lower	10
136	Sockeye	F	475	1.2	31-Jul	1	Riley Mouth	Upper	14
137	Coho	M	515	1.1	10-Aug	3	Pinnacle Mountain Area	Middle	13
138	Coho	M	487	2.1	3-Aug	2	Tatondan Lake	Upper	9
139	Coho	U	533	2.1	31-Jul	1	Eska Mouth Complex	Middle	12
140	Coho	M	547	--	9-Aug	2	Unknown	Unknown	5
141	Coho	U	456	2.1	3-Aug	2	Below Chickaloon River	Middle	15
142	Coho	M	504	2.1	4-Aug	2	Unknown	Unknown	6
143	Coho	M	541	2.1	3-Aug	2	Tatondan Lake	Upper	9
144	Coho	M	584	2.1	3-Aug	2	Wolverine	Lower	13
145	Coho	M	588	2.1	3-Aug	2	Tatondan Lake	Upper	9
146	Chum	M	598	--	3-Aug	2	Moose/Wolverine Mouths	Lower	14
147	Sockeye	M	495	1.2	3-Aug	2	Moose/Wolverine Mouths	Lower	18
148	Coho	F	536	2.1	3-Aug	2	Moose/Wolverine Mouths	Lower	10
149	Chum	F	587	--	12-Aug	3	Unknown	Unknown	0
150	Coho	F	560	2.1	7-Aug	2	Wolverine	Lower	9
151	Sockeye	M	570	--	26-Aug	5	Above Granite Mouth	Middle	7
152	Sockeye	M	548	--	17-Aug	4	Above Granite Mouth	Middle	17
153	Chum	F	490	0.2	26-Aug	5	Below Glenn Highway	Back Out	6
154	Coho	F	611	1.1	26-Aug	5	Pinnacle Mountain Area	Middle	8
155	Sockeye	M	549	1.2	26-Aug	5	Bartko	Lower	9
156	Chum	F	584	--	26-Aug	5	Moose/Wolverine Mouths	Lower	12
157	Chum	F	564	--	27-Aug	5	Moose/Wolverine Mouths	Lower	8

-continued-

Appendix B. continued.

Fish ID	Species	Sex	Length (mm)	Age	Tag Date	Tag Stratum	Spawning Location	Watershed Fate	Number of Detections
158	Coho	M	564	2.1	15-Aug	3	Tatondan Lake	Upper	8
159	Chum	F	588	--	11-Aug	3	Below Glenn Highway	Back Out	1
160	Chum	M	576	--	18-Aug	4	Unknown	Unknown	4
161	Coho	M	524	1.1	17-Aug	4	Riley Mouth	Upper	9
162	Coho	F	502	1.1	26-Aug	5	Wolverine	Lower	8
163	Chum	M	577		15-Aug	3	Moose/Wolverine Mouths	Lower	6
164	Coho	M	509	2.1	15-Aug	3	Tatondan Lake	Upper	10
165	Chum	F	625	--	18-Aug	4	Bartko	Lower	7
166	Coho	F	568	2.1	26-Aug	5	Tatondan Lake	Upper	8
167	Chum	M	581	--	26-Aug	5	Moose/Wolverine Mouths	Lower	14
168	Chum	M	605	--	13-Aug	3	Bartko	Lower	9
169	Sockeye	M	480	--	10-Aug	3	Moose/Wolverine Mouths	Lower	7
170	Sockeye	F	565	1.2	10-Aug	3	Eska Mouth Complex	Middle	4
171	Sockeye	M	585	UR	10-Aug	3	Moose/Wolverine Mouths	Lower	18
172	Sockeye	M	519	1.2	1-Aug	1	Pinnacle Mountain Area	Middle	12
173	Sockeye	M	504	1.2	30-Jul	1	Moose/Wolverine Mouths	Lower	16
174	Coho	F	584	2.1	15-Aug	3	Bartko	Lower	10
175	Sockeye	F	541	--	11-Aug	3	Above Granite Mouth	Middle	18
176	Chum	M	594	--	9-Aug	2	Moose/Wolverine Mouths	Lower	13
177	Coho	M	520	2.1	10-Aug	3	Tatondan Lake	Upper	10
178	Sockeye	M	487	1.2	11-Aug	3	Above Granite Mouth	Middle	13
179	Coho	M	539	2.1	13-Aug	3	Tatondan Lake	Upper	12
180	Chum	M	572	--	17-Aug	4	Below Glenn Highway	Back Out	6
181	Coho	M	545	UR	10-Aug	3	Moose Creek	Lower	4
182	Coho	F	507	UR	2-Aug	1	Eska Mouth Complex	Middle	12
183	Sockeye	F	515	1.2	9-Aug	2	Long Lake	Upper	12
184	Sockeye	F	488	UR	10-Aug	3	Pinnacle Mountain Area	Middle	13
185	Chum	M	616	--	3-Aug	2	Bartko	Lower	8
186	Coho	M	580	UR	10-Aug	3	Tatondan Lake	Upper	8
187	Coho	F	568	2.1	15-Aug	3	Tatondan Lake	Upper	11
188	Sockeye	F	548	UR	11-Aug	3	Moose/Wolverine Mouths	Lower	13
189	Coho	U	546	2.1	3-Aug	2	Tatondan Lake	Upper	10
190	Sockeye	F	549	2.3	10-Aug	3	Pinnacle Mountain Area	Middle	9
192	Chum	M	595	--	13-Aug	3	Below Glenn Highway	Back Out	3
193	Coho	U	524	2.1	9-Sep	6	Palmer	Lower	4
194	Coho	M	520	2.1	5-Sep	6	Bartko	Lower	6
195	Chum	F	592	--	18-Aug	4	Below Glenn Highway	Back Out	8
196	Sockeye	F	500	1.2	17-Aug	4	Eska Mouth Complex	Middle	14
197	Coho	M	571	2.1	15-Aug	3	Pinnacle Mountain Area	Middle	12

-continued-

Appendix B. continued.

Fish ID	Species	Sex	Length (mm)	Age	Tag Date	Tag Stratum	Spawning Location	Watershed Fate	Number of Detections
198	Coho	M	519	2.1	6-Sep	6	Bartko	Lower	5
199	Coho	M	499	2.1	8-Sep	6	Moose/Wolverine Mouths	Lower	7
201	Coho	F	550	2.1	15-Aug	3	Wolverine	Lower	11
202	Coho	F	552	2.1	5-Sep	6	Moose/Wolverine Mouths	Lower	12
203	Coho	F	617	1.1	11-Sep	6	Moose/Wolverine Mouths	Lower	9
204	Coho	F	577	2.1	6-Sep	6	Moose/Wolverine Mouths	Lower	7
205	Coho	F	589	2.1	17-Sep	6	Wolverine	Lower	5
206	Chum	M	630	--	12-Aug	3	Bartko	Lower	8
207	Sockeye	M	529	2.2	26-Aug	5	Moose/Wolverine Mouths	Lower	11
210	Coho	F	597	2.1	9-Sep	6	Moose Creek	Lower	2
211	Coho	U	551	2.1	11-Sep	6	Below Glenn Highway	Back Out	5
212	Coho	M	562	--	12-Sep	6	Unknown	Unknown	1
213	Sockeye	M	586	UR	26-Aug	5	Moose/Wolverine Mouths	Lower	12
214	Sockeye	F	540	--	11-Aug	3	Above Granite Mouth	Middle	16
215	Coho	M	468	1.1	3-Aug	2	Above Kings River Mouth	Middle	14
216	Coho	F	540	2.1	3-Aug	2	Above Kings River Mouth	Middle	8
217	Sockeye	M	614	--	9-Aug	2	Eska Mouth Complex	Middle	8
218	Sockeye	F	555	2.3	1-Aug	1	Above Granite Mouth	Middle	7
219	Coho	M	514	2.1	1-Aug	1	Bartko	Lower	12
220	Coho	f	578	UR	9-Aug	2	Wolverine	Lower	14
221	Sockeye	M	475	1.2	1-Aug	1	Long Lake	Upper	14
222	Coho	F	577	2.1	26-Aug	5	Tatondan Lake	Upper	8
223	Sockeye	M	475	UR	1-Aug	1	Moose/Wolverine Mouths	Lower	14
224	Coho	F	542	2.1	6-Aug	2	Tatondan Lake	Upper	10
225	Coho	M	594	--	3-Aug	2	Tatondan Lake	Upper	8
226	Coho	F	561	2.1	7-Aug	2	Above Kings River Mouth	Middle	9
227	Sockeye	M	580	1.2	6-Aug	2	Bartko	Lower	9
228	Coho	F	562	2.1	3-Aug	2	Tatondan Lake	Upper	8
229	Coho	F	558	2.1	5-Aug	2	Tatondan Lake	Upper	10
230	Sockeye	F	518	--	9-Aug	2	Ninemile to Gravel	Upper	7
231	Coho	F	564	2.1	3-Aug	2	Above Granite Mouth	Middle	13
232	Coho	F	579	2.1	3-Aug	2	Tatondan Lake	Upper	8
233	Chum	F	568	--	7-Aug	2	Granite Creek Watershed	Middle	9
234	Sockeye	F	565	1.3	26-Aug	5	Bartko	Lower	8
235	Chum	M	574	--	7-Aug	2	Moose/Wolverine Mouths	Lower	11
236	Sockeye	M	588	--	11-Aug	3	Moose/Wolverine Mouths	Lower	16
237	Coho	F	513	2.1	31-Jul	1	Below Chickaloon River	Middle	16
238	Coho	M	575	2.1	26-Aug	5	Moose/Wolverine Mouths	Lower	14
239	Chum	M	584	--	27-Aug	5	Moose/Wolverine Mouths	Lower	13

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Appendix B. continued.

Fish ID	Species	Sex	Length (mm)	Age	Tag Date	Tag Stratum	Spawning Location	Watershed Fate	Number of Detections
240	Chum	F	591	--	27-Aug	5	Below Glenn Highway	Back Out	2
241	Coho	F	525	2.1	26-Aug	5	Wolverine	Lower	9
242	Sockeye	M	544	--	26-Aug	5	Moose/Wolverine Mouths	Lower	12
243	Chum	M	562	--	26-Aug	5	Moose/Wolverine Mouths	Lower	14
244	Sockeye	F	554	1.3	10-Aug	3	Bartko	Lower	7
245	Sockeye	F	489	1.2	28-Aug	5	Eska Mouth Complex	Middle	7
246	Sockeye	M	512	1.2	11-Aug	3	Eska Mouth Complex	Middle	7
247	Sockeye	F	557	--	27-Aug	5	Unknown	Unknown	3
248	Coho	F	512	UR	12-Aug	3	Riley Mouth	Upper	7
249	Coho	M	556	--	12-Sep	6	Wolverine	Lower	9
250	Chum	F	579	0.2	18-Aug	4	Moose/Wolverine Mouths	Lower	11
251	Coho	M	542	2.1	31-Jul	1	Below Glenn Highway	Back Out	3
252	Coho	M	531	2.1	31-Jul	1	Tatondan Lake	Upper	8
253	Sockeye	F	552	1.2	18-Aug	4	Eska Mouth Complex	Middle	8
254	Sockeye	M	562	--	10-Aug	3	Eska Mouth Complex	Middle	9
255	Coho	M	548	UR	26-Aug	5	Tatondan Lake	Upper	7
256	Chum	U	639	--	11-Aug	3	Bartko	Lower	9
257	Chum	M	601	--	5-Aug	2	Moose/Wolverine Mouths	Lower	12
258	Coho	F	540	2.1	15-Aug	3	Eska Mouth Complex	Middle	12
259	Coho	m	581	2.1	9-Aug	2	Below Glenn Highway	Back Out	2
260	Coho	U	554	1.1	3-Aug	2	Above Kings River Mouth	Middle	10
261	Coho	F	544	2.1	10-Aug	3	Moose/Wolverine Mouths	Lower	13
262	Sockeye	F	468	1.2	1-Aug	1	Bartko	Lower	10
263	Sockeye	M	598	1.2	6-Aug	2	Eska Mouth Complex	Middle	13
264	Coho	F	584	2.1	15-Aug	3	Tatondan Lake	Upper	11
265	Chum	F	616	0.3	27-Aug	5	Below Glenn Highway	Back Out	4
266	Sockeye	F	471	2.2	1-Aug	1	Moose/Wolverine Mouths	Lower	18
267	Sockeye	F	575	1.2	10-Aug	3	Moose/Wolverine Mouths	Lower	13
268	Chum	M	641	--	10-Aug	3	Bartko	Lower	8
269	Sockeye	F	519	2.2	1-Aug	1	Riley Mouth	Upper	14
270	Sockeye	F	540	1.2	11-Aug	3	Riley Mouth	Upper	11
271	Sockeye	F	470	1.2	1-Aug	1	Pinnacle Mountain Area	Middle	5
272	Sockeye	M	580	--	11-Aug	3	Palmer	Lower	14
273	Sockeye	U	615	2.3	1-Aug	1	Pinnacle Mountain Area	Middle	10
274	Coho	F	550	2.1	10-Aug	3	Below Glenn Highway	Back Out	7
275	Coho	F	547	1.1	10-Aug	3	Above Kings River Mouth	Middle	13
276	Chum	F	607	--	15-Aug	3	Moose Creek	Lower	6
277	Coho	F	552	UR	26-Aug	5	Above Granite Mouth	Middle	5
278	Coho	F	589	UR	10-Aug	3	Above Kings River Mouth	Middle	10

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Appendix B. continued.

Fish ID	Species	Sex	Length (mm)	Age	Tag Date	Tag Stratum	Spawning Location	Watershed Fate	Number of Detections
279	Chum	M	619	--	18-Aug	4	Eska Mouth Complex	Middle	15
280	Chum	F	638	--	15-Aug	3	Bartko	Lower	9
281	Chum	F	564	--	18-Aug	4	Moose/Wolverine Mouths	Lower	13
282	Chum	F	616	--	18-Aug	4	Unknown	Unknown	4
283	Sockeye	F	496	2.2	17-Aug	4	Bartko	Lower	8
284	Coho	F	585	2.1	15-Aug	3	Bartko	Lower	11
285	Coho	F	563	1.1	12-Aug	3	Bartko	Lower	14
286	Coho	F	513	UR	17-Aug	4	Tatondan Lake	Upper	13
287	Sockeye	F	519	1.2	18-Aug	4	Moose/Wolverine Mouths	Lower	12
288	Sockeye	F	525	2.3	18-Aug	4	Above Kings River Mouth	Middle	11
289	Coho	F	564	2.1	17-Aug	4	Wolverine	Lower	12
290	Coho	M	603	2.1	15-Aug	3	Unknown	Unknown	1
291	Chum	M	612	--	17-Aug	4	Moose/Wolverine Mouths	Lower	13
292	Sockeye	M	586	--	18-Aug	4	Moose/Wolverine Mouths	Lower	12
293	Chum	F	622	--	12-Aug	3	Unknown	Unknown	2
294	Chum	F	589	--	18-Aug	4	Moose Creek	Lower	10
295	Sockeye	M	567	--	18-Aug	4	Moose/Wolverine Mouths	Lower	10
296	Chum	M	543	--	15-Aug	3	Moose/Wolverine Mouths	Lower	13
297	Chum	F	583	--	18-Aug	4	Below Glenn Highway	Back Out	3
298	Coho	F	562	2.1	17-Aug	4	Wolverine	Lower	10
299	Chum	F	562	0.4	13-Aug	3	Bartko	Lower	6
300	Sockeye	F	606	1.3	10-Aug	3	Pinnacle Mountain Area	Middle	7