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RUN TIMING AND SPAWNING DISTRIBUTION OF COHO AND LATE RUN CHINOOK SALMON IN THE KASILOF RIVER WATERSHED, ALASKA, 1987

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RUN TIMING AND SPAWNING DISTRIBUTION OF COHO AND LATE RUN CHINOOK SALMON IN THE KASILOF RIVER WATERSHED, ALASKA, 1987

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ABSTRACT

Chinook (Oncorhynchus tschawytscha) and coho (O. kisutch) salmon were studied during their migration to spawning grounds in the glacial Kasilof River watershed, Alaska in 1987. The hatchery enhanced early chinook salmon run returned in May and June to a tributary (Crooked Creek) at river kilometer (rkm) 11.3. The naturally occurring late run spawned in the mainstem, migrating past rkm 13.1 beginning about July 25. Two main spawning areas of late run chinook salmon were identified: the "slackwater" area below the outlet of Tustumena Lake (rkm 27-30), and the vicinity of the large bend at about rkm 16.

Coho salmon returns to Tustumena Lake tributaries were low in 1987; no early run was observed. Late-run fish were first observed at Indian Creek on October 1 and were present until the study ended in mid-November. Late-run coho salmon were also seen in Pipe, Glacier Flats, and Seepage Creeks.

Estimating the spawning escapement of late-run chinook salmon would be difficult in this glacial system. Sonar surveys or a floating weir might prove suitable to enumerate escapement but associated costs may be prohibitive. A mark-recapture study may be more cost effective with tag recovery activities in the two identified spawning areas.

Incidental Cook Inlet commercial catch probably includes late-run chinook salmon and early-run coho salmon bound for the Kasilof River. However, harvest estimates cannot be made without better knowledge of the composition and harvest rates of the mixed stocks.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Chinook (Oncorhynchus tschawytscha) and coho (O. kisutch) salmon in the Kasilof River have been subjected to increased harvest from commercial and sport fishermen in the last several years. These two species support two of the most popular sport fisheries on the Kenai Peninsula and are subjected to an intense commercial fishery targeting hatchery enhanced sockeye salmon (O. nerka) returning to Tustumena Lake (Figure 1). Concerns have been raised about the effects of this commercial harvest on naturally occurring salmon stocks. A one-year study was conducted in 1987 to determine the run timing and spawning distribution of chinook and coho salmon in the Kasilof River watershed.

Four species of salmon (chinook, coho, sockeye and pink [O. gorbuscha]) occur within the Kasilof River drainage. Sockeye salmon are the most important commercial species and the natural population has been enhanced with as many as 17 million fry a year (Flagg et al. 1986). The expected annual contribution of this enhancement program to the commercial fishery is 1.0-1.5 million adult sockeye salmon.

Most chinook salmon returning to the Kasilof River system are hatchery released, early-run fish that return in May and June to Crooked Creek, a tributary of the Kasilof River. A portion of the Crooked Creek escapement is artificially spawned in July at the Alaska Department of Fish and Game (Department) Crooked Creek Hatchery. Department sampling has indicated that chinook salmon run timing in the Kasilof River is bimodal. Theoretically, the second segment is a naturally occurring late run (Hammarstrom and Larson 1986). The presence of ripe unspawned adults below the outlet of Tustumena Lake as late as September 14 supports this theory (C. Burger, U.S. Fish and Wildlife Service, personal communication).

Coho salmon return to Crooked Creek Hatchery and tributaries of Tustumena Lake. Little information exists concerning naturally occurring coho salmon spawning areas in the Kasilof River watershed, although it is believed that Nikolai and Indian Creeks, respectively, are the primary early and late-run spawning streams. Other reports indicate that coho salmon are present in spawning streams by late August. Engel (1967) reported finding coho salmon in Nikolai and Shantatalik Creeks on August 27, 1967, and sport fishermen have reported early runs in Nikolai Creek, West Creek, and an unnamed tributary just downstream of the lake outlet. On September 29, 1986, U.S. Fish and Wildlife Service (Service) personnel counted 900 coho salmon in the lower 2 km of Indian Creek (U.S. Fish and Wildlife Service, Kenai Fishery Assistance Office, unpublished data).

The sport fishery on the Kenai Peninsula is expanding annually. In 1986, sport fishermen spent 26,000 angler days to harvest 8,100 chinook salmon out of a total early run of 12,000 in the Kasilof River (Hammarstrom and Larson 1986). Little is known of the sport harvest of coho salmon on the Kasilof River, but several drift boat river guides target this species throughout August and September. As more people

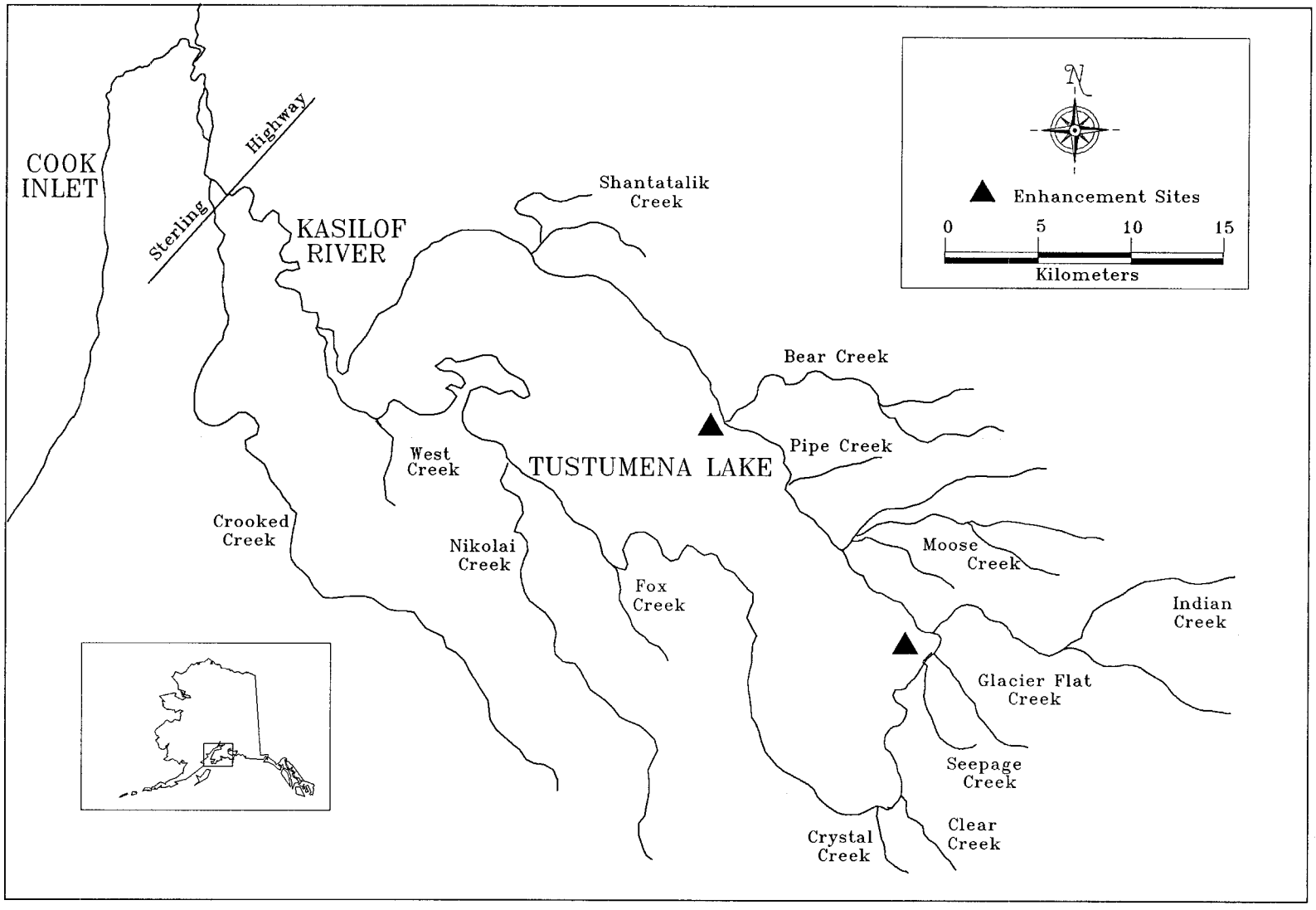

FIGURE 1.-Kasilof River and tributaries to Tustumena Lake, Alaska. Sockeye salmon enhancement sites are also indicated.

become aware of the coho and late-run chinook salmon in the Kasilof River drainage, the fishing pressure will probably increase. The late-run chinook and early-run coho salmon are incidentally harvested with the returning sockeye salmon. The high rate of exploitation (80-90%) necessary to prevent over-escapement of sockeye salmon (K. Tarbox, Alaska Department of Fish and Game, personal communication) may have an effect on these naturally occurring stocks of late-run chinook salmon and early-run coho salmon destined for the Kasilof River watershed.

Until better information on run sizes, run timing, and spawning areas is available, managers will not be able to develop strategies and priorities to prudently manage these species. This study was developed with the following objectives:

1. To determine run timing and spawning areas of late run-chinook salmon in the Kasilof River watershed.

2. To determine run timing and spawning areas of naturally occurring coho salmon in the Kasilof River watershed.

3. To investigate the feasibility of making a spawning escapement estimate of late run chinook salmon in the Kasilof River.

STUDY AREA

The Kasilof River watershed (Figure 1) is located within the Kenai National Wildlife Refuge (refuge) on the Kenai Peninsula approximately 130 km southwest of Anchorage. The headwaters are covered by Tustumena Glacier, an extension of the Harding Ice Field, which directly influences the water level and turbidity of Tustumena Lake and the Kasilof River. Tustumena Lake, with a surface area of 29,450 hectares, a length of 40 km, a width of 8 km and a maximum depth of 290 m, is one of the largest and deepest glacial lakes in Alaska. Melting of the glacier during summer raises the water level of the Kasilof River over a meter (B. King, Alaska Department of Fish and Game, personal communication) and reduces secchi disk transparency from about 15 to 1 cm.

Tustumena Lake has at least 12 perennial tributaries and is drained by the Kasilof River which flows approximately 32 km northwest into Cook Inlet. Crooked Creek is the main tributary entering at river kilometer (rkm) 11.3, and is the site of the Crooked Creek Hatchery. A two-basket fishwheel (Alaska Department of Fish and Game 1981) is located at rkm 13.1.

METHODS

Run Timing

Chinook salmon run timing information was determined by using the fishwheel catch (expanded for 24 hour operation) as an index (King and Tarbox 1987). The number of chinook salmon caught was plotted over time, along with information on color of each fish (red, pink, silver).

Run timing information for wild returning coho salmon was collected by observing fish during foot surveys of 10 Tustumena Lake tributaries (excluding West Creek, Figure 1) on a bi-weekly basis from mid-August to early November. When water clarity in a particular tributary was poor, a gillnet was drifted in or near the mouth to determine presence and relative abundance.

Spawning Site Identification

Chinook salmon spawning sites were determined primarily by monitoring the movements of fish tagged with radio transmitters. External transmitters were used because aquatic vegetation and substrate obstructions that might create snagging problems (Haynes and Gray 1979, Ross and McCormick 1981, Mellas and Haynes 1985) are minimal. To eliminate any potential equilibrium problems, tag weight was kept well below the maximum 2% of fish body weight (Winter 1983). To minimize stress, anesthetic was not administered (Wedemeyer 1970).

Chinook salmon were tagged throughout the run at the fishwheel site. Individuals to be tagged were chosen according to overall condition (activity, injury) and color. Fish to be tagged were retained in a holding box and a submerged tagging cradle (Hammarstrom and Larson 1986) was used to hold fish firmly without causing stress or injury. To further reduce stress, weights and scales were not taken. Length (mid-eye to fork of tail), sex, condition of fish, and radio tag frequency were recorded. Each transmitter was checked on the submerged fish for proper operation before release. Even though anesthetic was not used, the tagging procedure went smoothly and all fish were released immediately in good condition.

Chinook salmon were located on a weekly basis from a raft or aircraft. A spawning site was designated as that area where holding was detected toward the end of the last upstream migration. Fish that moved downstream after a period of holding were presumed to be dead or spawned out.

Radio tracking information was supplemented with observations of carcass concentrations that indicated past spawning activity in the area. In addition, spawning data was obtained from Crooked Creek Hatchery personnel who drifted a gillnet on September 10 and 11, from the outlet of the lake downstream to the end of the slackwater portion of the river (rkm 27).

A tributary was designated as a coho salmon spawning stream by confirming the presence of coho salmon in the stream. Up to 2 km of each stream were included in the surveyed area, and fish were counted to provide relative numbers by date and location.

Feasibility of Spawning Escapement Estimates for Chinook Salmon

To determine if spawning escapements can be estimated for chinook salmon, observations were made of sampling conditions in the mainstem river, including clarity, water velocity, fishing pressure, streambed substrate and obstructions.

RESULTS AND DISCUSSION

Chinook Salmon Spawning Behavior

Run timing.--Chinook salmon were captured at the fishwheel from July 2 to August 20 (Figure 2). The peak catch occurred the week of July 12-18, 1987. The total sample catch was 65 fish and the adjusted catch for 24 h operation was 185 fish. Past Department fishwheel counts indicated a possible separation of runs occurring about July 14 (Alaska Department of Fish and Game, unpublished data). While 1987 catches did not show an obvious separation between early and late runs (Figure 2), we did observe a distinct variation in maturity based on fish coloration. Dark colored (red) chinook salmon were caught from the start of fishwheel operations until August 12, and the first bright (silver) chinook salmon was caught on July 22. Percentages of bright fish were much higher after July 22, indicating a fresh, late run of fish after that date.

Spawning areas.--Movement patterns of 39 radio tagged chinook salmon (Table 1) varied considerably (Figure 3). Of the 39 fish tagged, 13 migrated downstream to Crooked Creek, eight moved downstream in the mainstem, 11 moved upstream, and seven were never located. Movement downstream to the Crooked Creek area after tagging was considered to be normal. However, two fish which moved to poor spawning habitat (slow, tidal water) in the lower 5 km of the river were considered to have exhibited abnormal behavior and were probably dead. Another fish that moved downstream was recovered from a setnet at Cohoe Beach, several km north of the Kasilof River. The fish was still bright, apparently in good condition, with no abrasions from the tag. This could have been an example of a fish entering a non-natal tributary (the Kasilof River) before retracing its path and moving into the proper stream (Liscom et al. 1978).

Possible explanations for the fate of the seven fish that were never relocated include the following: faulty tags, abnormal behavior that caused the fish to leave the study area quickly, unreported angler harvest, or exit from a non-natal stream after tagging. A mortality element on the radio transmitters would have helped in determining if a fish was holding and spawning in an area, or if it had died.

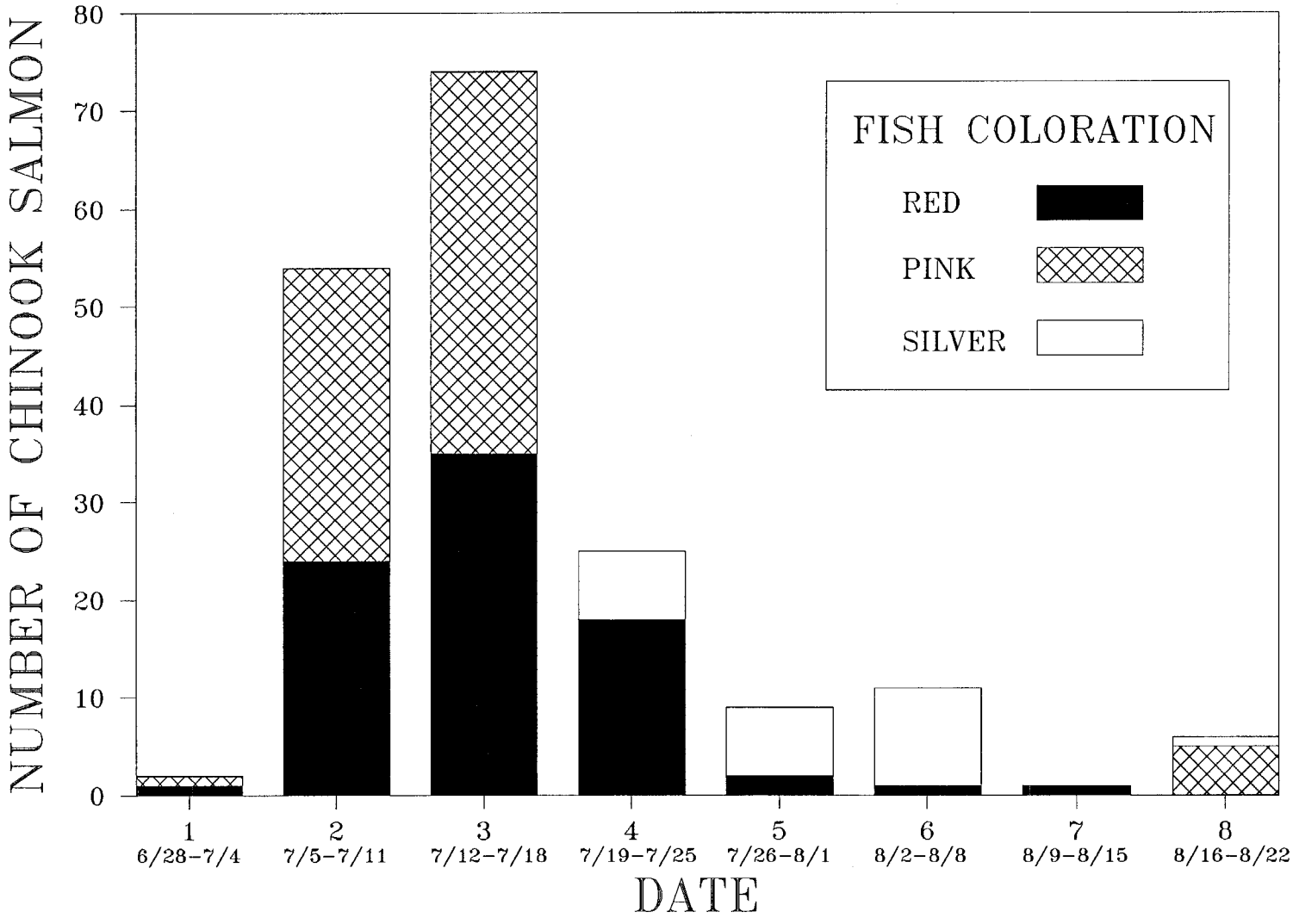

FIGURE 2.-Weekly chinook salmon fishwheel catch by maturation (color), adjusted for 24 h operation, Kasilof River, Alaska, 1987.

TABLE 1.-Vital statistics and final destinations of radio tagged chinook salmon, Kasilof River watershed, Alaska, 1987.

Date	Frequency (mHz)	Length (mm)	Sex	Coloration	Final Destination
7/8	40.800	620	F	Pink	Crooked Creek
7/8	40.790	780	F	Pink	Crooked Creek
7/10	40.811	680	F	Red	Crooked Creek
7/10	40.842	830	M	Red	Upstream rkm 16
7/10	40.771	590	M	Pink	Crooked Creek
7/13	40.600	580	M	Pink	Crooked Creek
7/13	40.638	790	M	Red	Crooked Creek
7/13	40.610	790	M	Red	Crooked Creek
7/16	40.648	650	M	Pink	Crooked Creek
7/21	40.620	580	M	Red	Crooked Creek
7/22	40.840	660	F	Silver	Upstream rkm 16
7/22	40.591	630	M	Red	Crooked Creek
7/23	40.630	580	F	Silver	Downstream rkm 13
7/23	40.725	740	F	Red	Crooked Creek
7/24	40.670	790	F	Red	Crooked Creek
7/27	40.801	880	F	Red	Downstream rkm 11
7/27	40.770	720	F	Silver	Upstream rkm 28
7/29	40.750	630	F	Silver	Did not locate
7/29	40.810	830	F	Silver	Cohoe Beach
7/29	40.570	940	F	Silver	Did not locate
7/29	40.628	370	M	Silver	Did not locate
7/31	40.680	970	F	Silver	Upstream rkm 19
7/31	40.820	990	F	Red	Upstream rkm 29
7/31	40.611	330	M	Red	Downstream rkm 12
8/3	40.780	990	F	Silver	Did not locate
8/3	40.700	860	M	Silver	Downstream rkm 12
8/3	40.860	920	F	Silver	Did not locate
8/3	40.849	680	M	Silver	Downstream rkm 1
8/3	40.710	890	F	Silver	Did not locate
8/3	40.831	980	F	Silver	Upstream rkm 19
8/6	40.761	680	F	Silver	Upstream rkm 28
8/6	40.771	760	F	Silver	Upstream rkm 21
8/6	40.731	920	F	Silver	Crooked Creek
8/18	40.810	910	F	Pink	Downstream rkm 12
8/18	40.740	970	F	Pink	Upstream rkm 17
8/18	40.591	1020	F	Pink	Did not locate
8/18	40.723	960	F	Pink	Upstream rkm 15
8/20	40.868	990	F	Pink	Downstream rkm 5
8/20	40.648	950	F	Silver	Upstream rkm 16

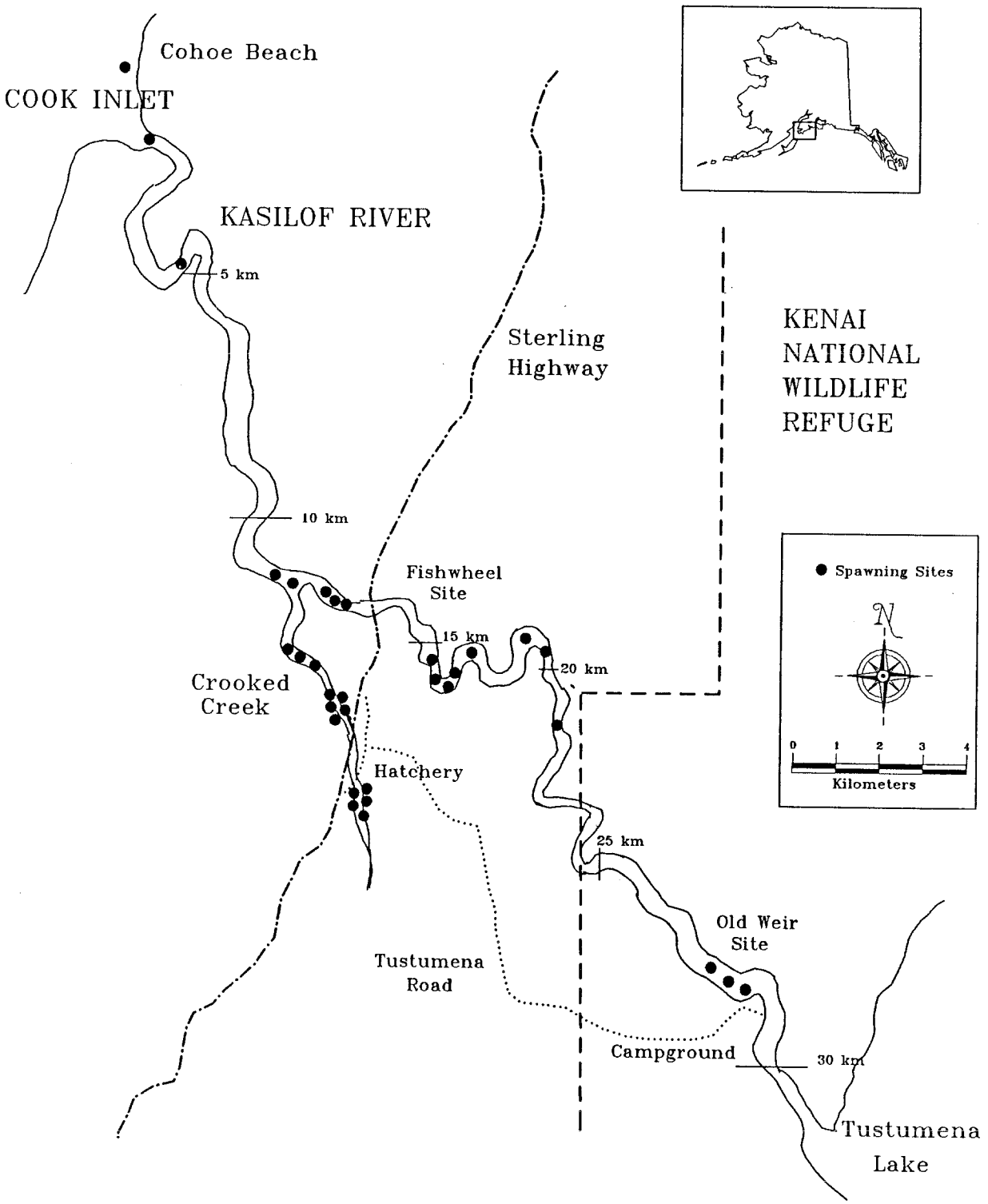

FIGURE 3.-Spawning sites of radio tagged chinook salmon, Kasilof River watershed, Alaska, 1987.

There was some upstream and downstream movement between spawning areas before individual fish selected a final spawning destination. Tagged chinook salmon selected spawning locations in three areas: Crooked Creek, the mainstem slackwater area (rkm 27-30), and a large mainstem gravel bar at rkm 16 (Figure 3).

Spawning movements in the mainstem and into Crooked Creek differed significantly between fish radio tagged before and after July 25 (X^2 = 15.2, P <.001). Of the 15 fish tagged before July 25, 80% migrated downstream into Crooked Creek and 20% remained in the mainstem. Conversely, of the 17 fish tagged and located after July 25, only 6% migrated to Crooked Creek and 94% remained in the mainstem. This data, coupled with the maturity data presented in the previous section, suggests that two distinct chinook salmon runs occur in the Kasilof River watershed. The early run reaches rkm 13.1 (and presumably Crooked Creek) during the first three and one half weeks of July and spawns in Crooked Creek, while the late run reaches rkm 13.1 primarily during the last week of July and the first three weeks of August and spawns in the mainstem. In the Kenai River, 30 km north of the Kasilof River, Burger et al. (1985) found that an early run of chinook salmon entered the river in May and June and spawned in tributaries, and a late run entered the river from late June through August and spawned in the mainstem.

The mean length of 13 fish tracked to Crooked Creek was 703 mm compared to a mean length of 847 mm (excluding one jack) of 15 fish spawning in the mainstem (Table 2). Using a one-tailed t-test, we concluded with 95% confidence that mainstem spawners averaged more than 50 mm greater in length than Crooked Creek spawners (t = 3.09, P = .002).

TABLE 2.-Mean lengths of radio tagged chinook salmon (excluding jacks, those not located or believed dead), Kasilof River watershed, Alaska, 1987.

Location	N	Mean length (mm)
Crooked Creek		
Male	7	659
Female	6	755
Total	13	703
Mainstream		
Male	2	845
Female	13	847
Total	15	847

Three tagged fish selected spawning sites in the transition zone (rkm 27-30) between Tustumena Lake and the Kasilof River. This area traditionally known as the slackwater area, has previously been identified as an important spawning area for 2,000-3,000 late-run chinook salmon (Flagg 1986). Our study supports the theory that late-run fish spawn in the slackwater area, as the fish tracked to the area passed rkm 13.1 later and in much brighter condition than Crooked Creek fish.

Presence of late-run chinook salmon in the slackwater area was further verified on September 10 and 11, 1987, by hatchery personnel who drifted gillnets from the outlet of Tustumena Lake (rkm 32) to the area of the old fish weir site (rkm 27). Approximately 200 mature chinook salmon were caught between rkm 30 and 27.

The spawning area at rkm 16 had not been previously identified. During this study three tagged salmon were tracked to this area. Additional evidence of the importance of this area for spawning was obtained while tracking two fish in the area on August 31, 1987, when 25 chinook salmon carcasses were found on the inside bend. On September 17 and 23, 73 and 82 carcasses were counted, respectively. Another 33 carcasses were found two bends downriver at rkm 15 on September 23.

Coho Salmon Spawning Behavior

No coho salmon were observed in any of the tributaries before October 1 (Table 3). Our results were confirmed by local fishermen who indicated that 1987 was a poor year for early-run coho salmon and few fish were caught during this period.

Coho salmon were sighted in Indian, Pipe, Glacier Flats, and Seepage Creeks well past the expected timing (August) of an early run. Coho salmon were first seen in the lower 100 m of Indian Creek on October 1, 1987, with a count of 200 fish. Further surveys at Indian Creek revealed the presence of coho salmon through November 9. On November 9, 931 coho salmon were counted in the lower 400 m. Using an estimated counting efficiency of 50% due to water turbidity, depth and glare, it is likely that twice this amount, or 1,862 fish were present. These fish were mostly pink or red in color and in good condition. An aerial observation by refuge personnel confirmed the presence of coho salmon in Indian Creek on November 24, 1987 (W. Larned, Kenai National Wildlife Refuge, personal communication). During other surveys, two coho salmon were found in the lower 1 km of Pipe Creek on October 27, 46 in Glacier Flats Creek and 15 in Seepage Creek on November 9, 1987.

No coho salmon were observed in Nikolai Creek during our surveys, but sport fishermen reported catching two coho salmon on August 20 and one on September 2, 1987. By October 27, the bottom ice forming in Nikolai Creek eliminated the possibility of any further successful spawning for the year.

TABLE 3.-Escapement counts of coho salmon by date and tributary, Kasilof River watershed, Alaska, 1987.

Stream	Date						
	Aug. 17-20	Sept. 1-2	Sept. 15-16	Oct. 1-2	Oct. 27	Nov. 9	Nov. 24
Shantatalik	0	0	0	0	0	0	
Bear	0	0	0	0	0	0	
Pipe	0	0[b]	0[b]	0	2	0	
Moose	0	0	0	0		0	
Indian	0[ab]	0[ab]	0	200	present[b]	931	[f]
Glacier Flats	0	0	0	0	[e]	46	
Seepage	0	0	0	0	0	15	
Clear	0	0	0	0	0	0	
Crystal	0	0	0	0	0	0	
Nikolai	0[bc]	0[bd]	0[b]	0	[d]		
West			0[b]	0			

[a] Unable to count due to glacial turbidity.
[b] Drifted a gillnet at the mouth.
[c] Sport fishermen reported catching 2 coho salmon.
[d] Sport fishermen reported catching 1 coho salmon.
[e] Not surveyed due to bad weather and boat mechanical problems.
[f] Coho salmon observed from refuge aircraft, but not counted.

Indian Creek coho salmon runs began after September 16 and continued until at least mid-November in 1987. Both bald eagles (Haliaecetus leucocephalus) and brown bears (Ursus arctos) used this late run as a food source. The timing of the late runs in Pipe, Glacier Flats and Seepage creeks appeared to be later than Indian Creek (Table 3), if in fact, these were annual self-perpetuating runs rather than individuals straying from Indian Creek. During surveys on July 20, August 27, September 12, and October 12, 1967, spawning coho salmon were not located in Glacier Flats and Seepage Creeks (Engel 1967). With a 5% straying rate for coho salmon (Peck 1970, Hasler and Scholz 1983), and considering the nearness of Glacier Flats and Seepage Creeks, Indian Creek could have been the origin of all the late-run coho salmon observed.

Feasibility of Spawning Escapement Estimates for Chinook Salmon

Estimating the spawning escapement of late-run chinook salmon would be difficult in the Kasilof River for the following reasons: (1) the river is turbid, fast, and shallow with numerous obstructions; (2) high water conditions occur periodically; (3) angling effort by sportfishermen is low; and (4) four species of salmon migrate up the river, with chinook salmon being the least abundant. Due to these constraints, numeric counts from an aircraft or raft, creel surveys, and fixed weirs would not be suitable methods to enumerate escapement. Sonar surveys and floating weirs might be able to be used on the Kasilof River, but the costs associated with these two methods would most likely be prohibitive.

The most cost-effective method to estimate chinook salmon escapement would be to tag fish at the fishwheel and then recover tags using drift gillnetting and carcass counts. Fish should be selected for tagging by run timing and coloration to avoid fish bound for Crooked Creek. Drift gillnetting could be employed at the two mainstem spawning areas at rkm 16 and 27-30 (Figure 3); gillnetting could be coordinated with Department egg takes to avoid unnecessary harassment of spawning fish. Carcass counts could be used to supplement drift gillnetting if insufficient numbers of tagged fish were recaptured; carcasses would have to be removed or marked to avoid duplicate counts.

Management Implications

Run timing.--An assessment of the impact of the sockeye salmon commercial fishery on coho and chinook salmon runs is difficult because it is a mixed stock fishery. Within this mixed stock fishery different species are harvested at different rates, different fishing methods (set net, drift net) catch fish at different rates, and different stocks have different run timing and migration routes which make them susceptible to harvest at different rates. In spite of these difficulties, it is possible to make theoretical estimates by evaluating Kasilof River runs with data from the nearby Kenai River.

Our data shows that run timing of late-run chinook salmon into the Kasilof River drainage appears to overlap with the timing of the intense commercial harvest of sockeye salmon. In most years, run timing of early-run coho salmon probably overlaps as well. Using a migration rate of 1.6 km per day for Kenai River chinook salmon (Burger 1983), the first of the late-run chinook salmon caught in the fishwheel (on July 22) would have been at the mouth of the Kasilof River 8 days earlier (July 14). This would have been during the continuous commercial set net fishing openings, so chinook salmon bound for the Kasilof River were probably intercepted.

Although the Kasilof River escapement of late-run chinook salmon is unknown, it is probably between 1,000 and 5,000 fish (Flagg 1986). Escapement estimates of Kenai River late-run chinook salmon averaged 63,239 from 1984-1987 (Hammarstrom and Larson 1986, Hammarstrom and Larson 1987, Conrad and Larson 1987, Conrad and Hammarstrom 1988) with a high of 76,070 and a low of 48,500. Cook Inlet commercial harvests of the mixed chinook salmon stocks varied from 5,805 to 21,379 fish with an average of 15,669 (Ruesch 1988). Using a range of each of these parameters, harvest rates (harvest divided by escapement) were all below 40% (Table 4). Harvest rates of 40% or less on a natural chinook salmon stock should not place that stock in danger, assuming sport harvests are not excessive (if legalized) and total run size remains high enough to provide adequate escapement.

August 15-25 is generally accepted as the peak of coho salmon activity at Nikolai Creek. A local outfitter who maintains a temporary tent camp at the mouth of Nikolai Creek, reports a small early run of coho salmon into Nikolai Creek with peak sport fishing between mid and late August (D. Kishbaugh, personal communication). A migration rate of 3.2 km per day (Bentz 1987) would put these fish at the mouth of the Kasilof River two weeks earlier, on approximately July 31. Commercial catch records show that 75,000 coho salmon were harvested in set nets on the east side of Cook Inlet in 1987. Approximately 58% of this harvest occurred between July 31 and August 14 with the peak occurring on August 6, 1987 (Browning 1988 and Ruesch 1988). This harvest is well above the long-term average (1966-1986) east side set net harvest of 44,000 coho salmon (Ruesch 1987). The increased harvest is attributed to a large return of early-run Kenai River coho salmon and increased commercial fishing periods targeting surplus Kasilof and Kenai River sockeye salmon (Ruesch 1988). Commercial catches of coho salmon in drift gill nets in 1987 also exceeded the long-term average but these catches are reported for the entire central district and include catches from the west side of Cook Inlet. The commercial harvest undoubtedly includes naturally occurring, early-run coho salmon from the Kasilof River watershed. Until the proportion of coho salmon in the mixed stock fishery near the Kasilof River is known, conclusions about the impact of commercial fishing activity on early-run coho salmon cannot be made with certainty.

Spawning areas.--Of the two primary late-run chinook salmon spawning areas found on the upper Kasilof River, one is located on the Kenai National Wildlife Refuge and the other is approximately 8 km downstream

TABLE 4.-Theoretical harvest rates of Kasilof River late-run chinook salmon based on variable Kenai and Kasilof River escapements and Cook Inlet chinook salmon harvests.

Kasilof population	Kenai population	Kenai: Kasilof ratio	Cook Inlet harvest	Kasilof harvest	Kasilof harvest rate
500	75,000	150:1	20,000	132	26%
3,000	75,000	25:1	20,000	769	26%
10,000	75,000	7.5:1	20,000	2,353	24%
500	50,000	100:1	20,000	198	40%
3,000	50,000	16.7:1	20,000	1,130	38%
10,000	50,000	5:1	20,000	3,333	33%
500	75,000	150:1	12,000	79	16%
3,000	75,000	25:1	12,000	462	15%
10,000	75,000	7.5:1	12,000	1,412	14%
500	50,000	100:1	12,000	119	24%
3,000	50,000	16.7:1	12,000	462	23%
10,000	50,000	5:1	12,000	1,412	20%
500	75,000	150:1	8,000	40	11%
3,000	75,000	25:1	8,000	308	10%
10,000	75,000	7.5:1	8,000	914	9%
500	50,000	100:1	8,000	79	16%
3,000	50,000	16.7:1	8,000	452	15%
10,000	50,000	5:1	8,000	1,333	13%

of the refuge boundary (Figure 3). The Department's Fisheries Rehabilitation, Enhancement and Development Division would like to enhance this late run and took 62 females from the upper spawning area to see if this stock was disease-free and genetically different from the Crooked Creek stock. The refuge manager should be aware of this late-run stock and ensure that any enhancement activities by the Department are compatible with the purposes of the refuge and the Service's Recreational Fisheries Policy.

ACKNOWLEDGEMENTS

We would like to express appreciation to the Alaska Department of Fish and Game for their assistance in several facets of this study. Special thanks are extended to Bruce King and other Soldotna Office Commercial Fisheries Division personnel for their assistance in providing the design and pontoon floats for the chinook salmon holding pen, and after their operations were completed, allowing us to use the fishwheel until the end of the chinook salmon run. Thanks to the personnel at the Crooked Creek Hatchery who recovered our radio tags from fish that returned to the hatchery and for the information on their gillnetting operations in the slackwater section of the upper Kasilof River. Most importantly, thanks to the workers who contributed to this project: co-workers Jeff Booth and Mary Wunderlich Faurot; Student Conservation Association volunteers Tim Edgar, R.D. Nelle, Ted Otis, and Brad Weinischke; and Kenai National Wildlife Refuge pilots Bill Larned and Bob Richey.

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