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Distribution, Stock Composition, and Location and Habitat Type of Spawning Areas Used by Sockeye Salmon on the Taku River

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DISTRIBUTION, STOCK COMPOSITION, AND LOCATION AND HABITAT TYPE OF SPAWNING AREAS USED BY SOCKEYE SALMON ON THE TAKU RIVER.

by

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ABSTRACT

Radio telemetry was used to determine the distribution of adult sockeye salmon (Oncorhynchus nerka) returning to the Taku River in 1984 and 1986, and locate and classify spawning areas used by this species. Escapement estimates were made for the component stocks of the run. Three hundred and seventy-five sockeye salmon were tagged with radio transmitters during the study. A substantial portion of the run utilized spawning areas on the main stem Taku River. Several important spawning areas were also located in the upper portion of the drainage. Differences in run timing were observed for the component stocks. The majority of sockeye salmon returning to the main stem spawned in side channels, spawning areas not typically associated with this species. Over 48% of the sockeye salmon using main stem areas had migrated to saltwater during their first year of life.

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INTRODUCTION

Sockeye salmon (Oncorhynchus nerka), an important species of salmon in the North Pacific, is of commercial significance to the United States and Canada. The Pacific Salmon Treaty of 1985 attempts to manage salmon on a coast-wide basis and calls for cooperative research to obtain information on salmon resources shared by both countries. One issue specifically addressed by the Treaty is the salmon resource on the transboundary rivers: rivers with their headwaters in Canada that flow through the U.S. before reaching salt water.

The Taku River, a transboundary river located near Juneau, Alaska (Fig. 1), supports a major run of sockeye salmon that are harvested commercially by U.S. and Canadian fishermen. Prior to 1984, relatively little was known about Taku River sockeye salmon other than limited information on distribution of spawners within the system, run timing and catch statistics from the U.S. commercial fishery in Taku Inlet.

In 1984 and 1986, we used radio telemetry to determine the distribution of sockeye salmon returning to the Taku River and location of important spawning areas. This study was part of a cooperative research program conducted by the Alaska Department of Fish and Game (ADF&G), the Canadian Department of Fisheries and Oceans (DFO) and the National Marine Fisheries Service (NMFS) Auke Bay Laboratory to meet Treaty commitments to assess salmon resources on the Taku River.

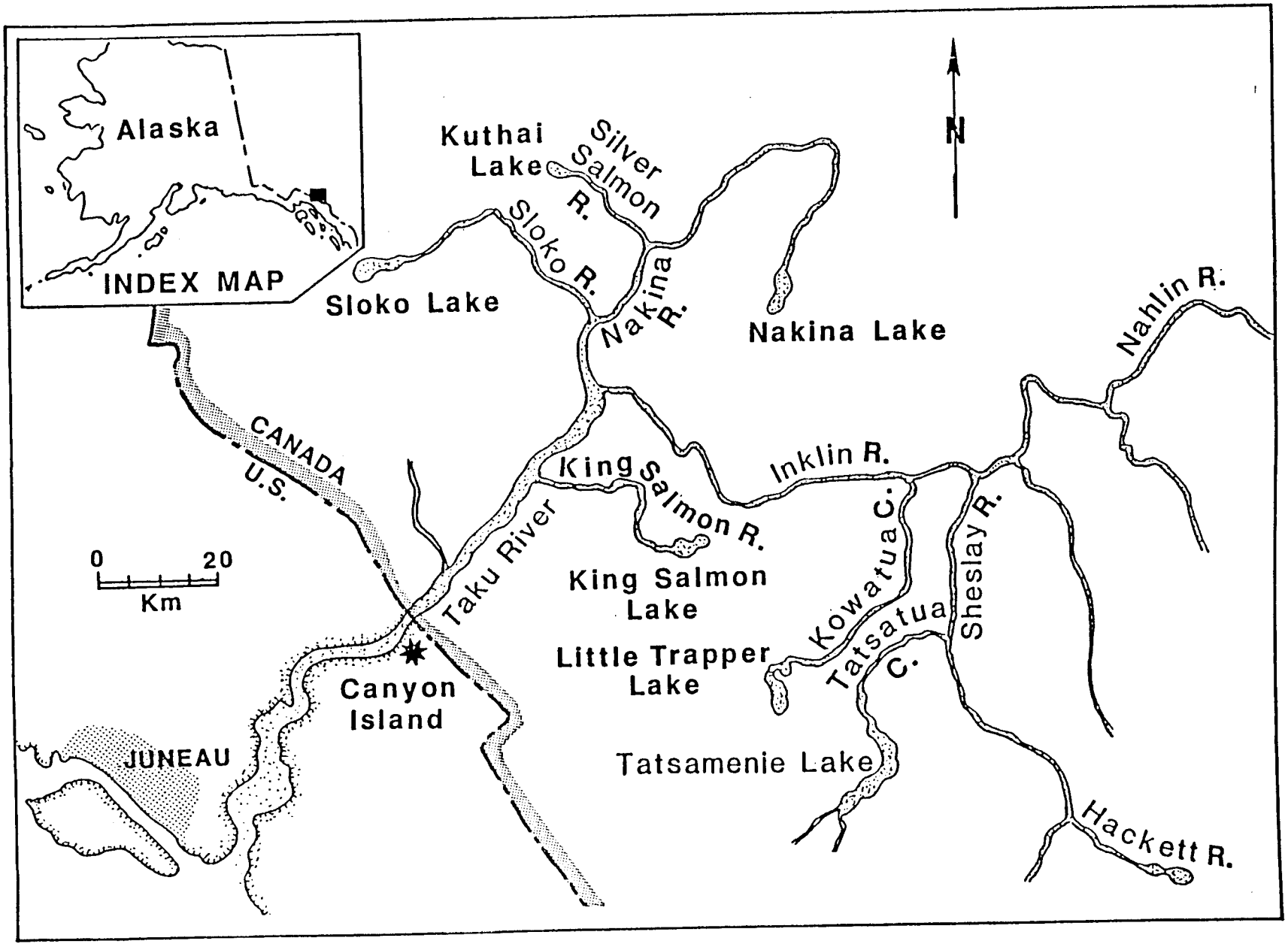

Figure 1.--Taku River drainage

STUDY AREA

The Taku River is a large glacial (turbid) river, draining a watershed of over 16,000 km^2. Approximately 95% of the system is located in Canada (Fig. 1). The system is relatively inaccessible with access limited mostly to aircraft.

The river is characterized by extensive braiding on the main stem (numerous side channels and sloughs), fast moving water in the central portion of the drainage, and slow, meandering tributaries in the upper reaches. Water visibility is extremely poor due to the turbidity of the river; only a few tributaries are clear, including the King Salmon, Nakina (above the confluence with the Sloko River), Silver Salmon, Nahlin, and Hackett Rivers.

Sockeye salmon destined for the Taku River are harvested by U.S. fishermen in Taku Inlet. A commercial gill net fishery also occurs within the Canadian portion of the Taku River from the U.S./Canadian border to 15 km upstream. Weirs, located at the outlet of Little Trapper Lake, Little Tatsamenie Lake and the mouth of the Hackett River, are used to count adult salmon returning to these systems.

MATERIALS AND METHODS

Adult sockeye salmon moving upstream were captured with fish wheels located at Canyon Island, 4 km below the U.S./Canadian border (Fig. 1). In 1986, fish wheels were also operated near the mouth of the river.

Sockeye salmon were tagged with radio transmitters (30-31 MHz frequency range) placed in the stomach of the fish. The transmitters used in 1986 were equipped with motion sensors and mortality sensors (that indicated when a transmitter had not moved for over 6 h). The fish were also marked externally with spaghetti tags attached below the dorsal fin.

Fish tagged with radio transmitters were located weekly by boat or fixed-wing aircraft equipped with receiving antennas. Helicopters equipped with receiving antennas were used to locate radio-tagged fish on the spawning grounds and access these areas for collecting samples. Spawning areas were classified into general habitat types (Table 1).

Population estimates were obtained for the component stocks of sockeye salmon on the Taku River by allocating the estimated population for the entire river into the component stocks based on the distribution of the radio-tagged fish. Population estimates were calculated weekly using data from mark/recapture studies conducted on Taku River sockeye salmon during 1984 and 1986 (Clark et al. 1986; McGregor and Clark 1987); stock composition was determined based on the distribution of radio-tagged fish. These estimates and their precision were computed using the bootstrap technique (Efron 1982). The data sets (population and distribution) for each period were resampled 1,000 times to obtain the estimates. The 1984 and 1986 data for estimating population were restratified, combining information for certain weeks due to small sample sizes.

Table 1.--General habitat categories used to describe spawning areas used by sockeye salmon on the main stem Taku River.

Habitat Type	Description
Main stem	Primary river channel, characterized by high velocities and year round stream flow. Changes in groundwater and tributary inflow is inconsequential to overall stream characteristics. Suspended sediment and turbidity are high from late spring to fall.
Side Channel	Secondary river channels characterized by shallower depths, lower velocities and smaller streambed material than main channel areas. Water source may include water entering direct from the main channel, depending on water level of main channel, which may vary during the year.
Upland Slough	Areas that convey water from upwelling ground water and small tributaries to the main river, but are not interconnected with the main stem at the upper end. Characterized by the presence of beaver dams and acccumulation of silt covering the substrate.
Tributary	Characteristics reflect the hydrological and morphological attributes of the drainage. The physical characteristics are usually not dependent on main stem conditions.
Tributary Mouth	Uppermost point of a tributary influenced by main stem river or slough backwater effects.
Lake	Lentic environment receiving water from springs, surface runoff or small tributaries.
Upwelling Basin	Shallow off-channel water body formed by upwelling groundwater.

RESULTS AND DISCUSSION

Tagging

Three hundred and seventy-five sockeye salmon were tagged with radio transmitters; 93 in 1984 and 282 in 1986 (Table 2). Two hundred and fifty-three (67%) fish were tracked to their final destination. The remaining fish either died after being tagged (due to predation or handling), were lost after being tracked upriver or moved out of the river system into Taku Inlet.

Table 2.--Tagging results from radio telemetry studies on the Taku River, 1984 and 1986.

	Total		1984		1986	
Number tagged	375		93		282	
Number tracked upriver from tagging site	253	(67%)	74	(80%)	179	(63%)
Number caught in Canadian fishery[a]	49	(20%)	19	(26%)	30[b]	(18%)
Number tracked to spawning grounds[a]	205[c]	(80%)	56[c]	(74%)	149	(82%)

[a]Percent of fish that moved upriver.
[b]Based on the 167 fish that moved into Canada; 12 of the 179 fish tagged with radio transmitters remained in the U.S. portion of the river.
[c]Includes one fish that was caught in the Canadian fishery, but had remained on the main stem Taku River for over 40 days.

Distribution

Twenty percent (49) of the fish tagged with radio transmitters were caught in the Canadian gill net fishery; 26% in 1984 and 18% in 1986 (Table 2). These catch statistics were similar to exploitation rates of sockeye salmon reported for the Canadian fishery on the Taku River by Clark et al. (1986) and McGregor and Clark (1987); 20.4% and 14.0% in 1984 and 1986, respectively.

Two hundred and five radio-tagged sockeye salmon were tracked to spawning areas within the river system (Table 2). A large portion of these fish used main stem areas for spawning (Figs. 2, 3). Substantial numbers of radio-tagged fish were also located in the Nakina River, Kowatua Creek, and Tatsatua Creek (Fig. 1). Small numbers of fish traveled to other areas within the drainage, including the Inklin, Nahlin, and Hackett Rivers. The distribution of the radio-tagged fish for 1984 and 1986 is summarized by discrete weeks of the run. (Tables 3, 4).

Distribution information for 1984 probably underestimated the importance of Nakina River and Kowatua Creek stocks because based on population estimates (Clark et al. 1986), only the last one-third of the run was sampled. In 1984, we did not begin radio-tagging fish until mid-July. Recoveries of spaghetti-tagged fish in 1984 indicated that most of the sockeye salmon bound for the Nakina River and Kowatua Creek migrated past Canyon Island prior to mid-July (Clark et al. 1986). Distribution information for 1986 revealed that a substantial portion of the Nakina River and Kowatua Creek stocks moved through the lower river by mid- to late July (Table 4).

Population Estimates

Our estimate (133,034) for the total run of sockeye salmon returning to the Taku River in 1984 was similar to the 133,414 estimated by Clark et al. (1986). McGregor and Clark (1987) estimated that 105,109 sockeye returned to the Taku River in 1986. We estimated that 93,436 sockeye salmon returned to the

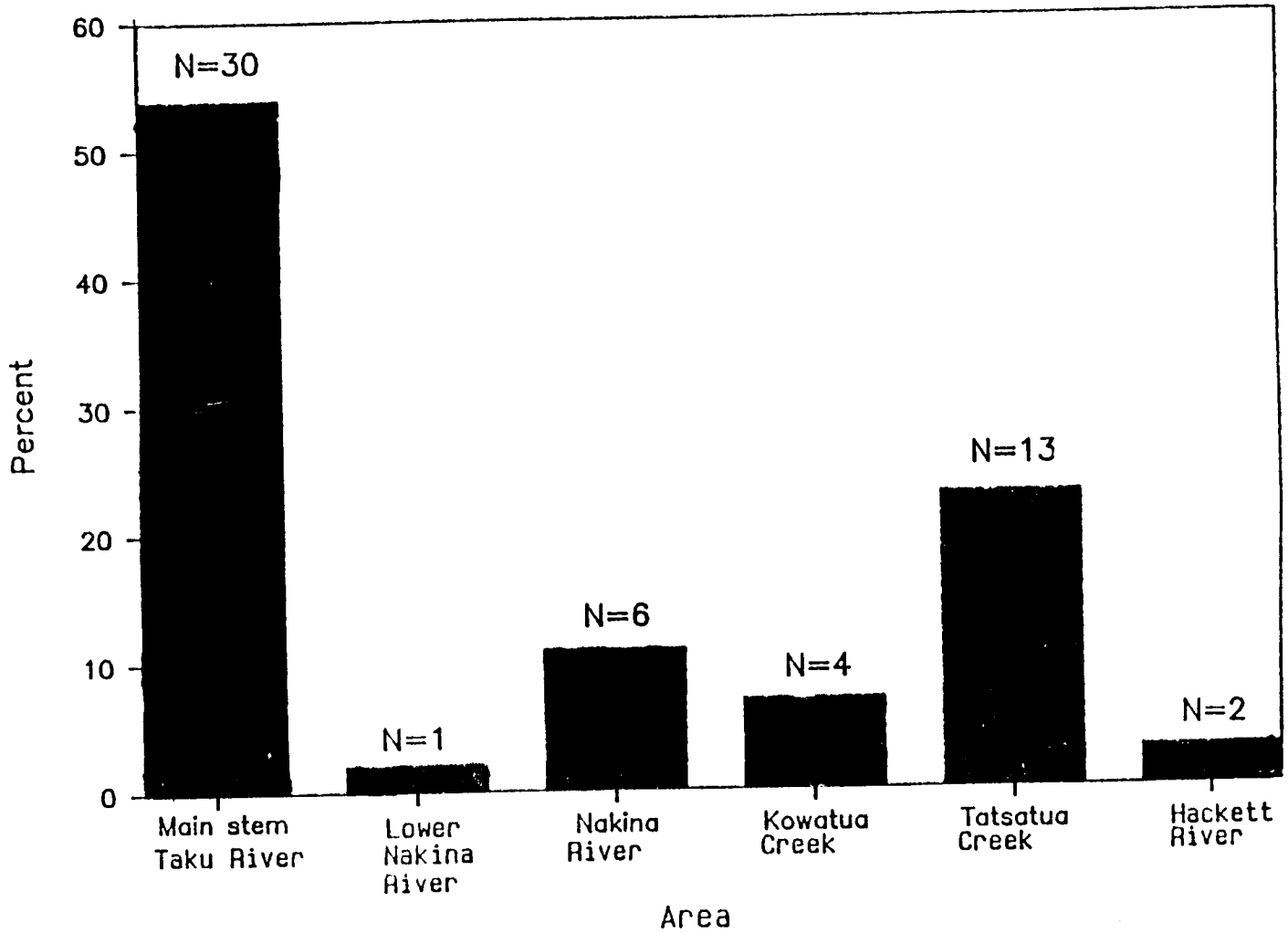

Figure 2.--Distribution of radio tagged adult sockeye salmon on the Taku River system in 1984.

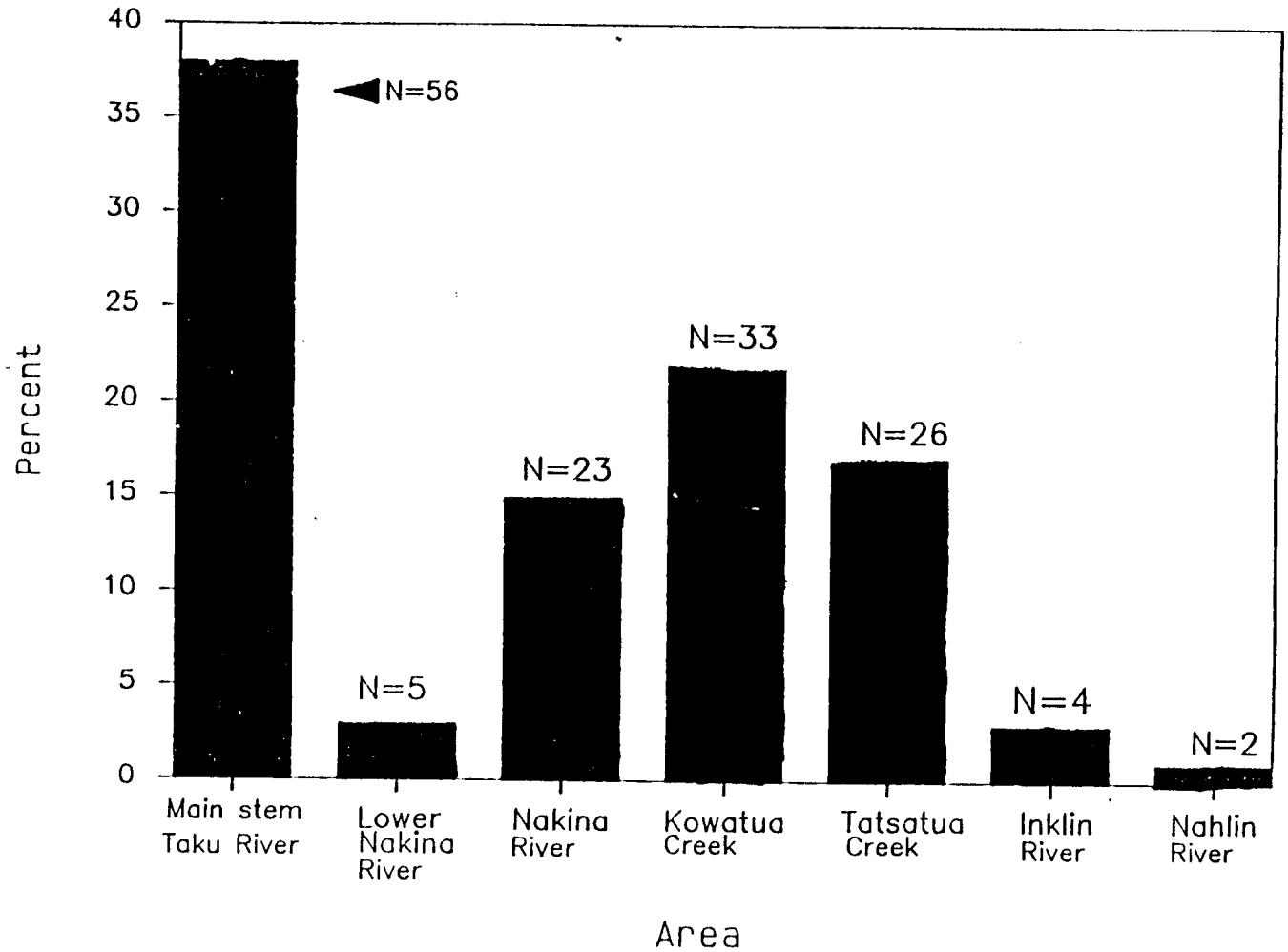

Figure 3.--Distribution of radio tagged adult sockeye salmon on the Taku river system in 1986.

Table 3.--Distribution of adult sockeye salmon tagged with radio transmitters on the Taku River system during discrete periods of the run, 1984.

Area	Tagging period						Total for area
	7/15-21	7/22-28	7/29-8/4	8/5-11	8/12-18	8/19-25	
Main stem	-	6	5	7	8	4	30
Nakina River[a]	-	1	-	-	-	-	1
Nakina River[b]	-	3	3	-	-	-	6
Kowatuka Creek	-	3	1	-	-	-	4
Tatsatua Creek	-	1	3	3	3	3	13
Hackett River	-	-	2	-	-	-	-
Weekly total	-	14	14	10	11	7	56

[a]Portion of the river below the confluence with the Sloko River.
[b]Includes fish destined for the Silver Salmon and Sloko Rivers which are tributaries of the Nakina River.

Table 4.--Distribution of adult sockeye salmon tagged with radio transmitters on the Taku River system during discrete periods of the run, 1986.

Area	Tagging period					
	6/15-21	6/22-28	6/29-7/5	7/6-12	7/13-19	7/20-26
Main stem (U.S.)	-	1	2	1	1	2
Main stem (Canada)	1	3	2	3	2	5
Nakina River (lower)[a]	1	-	-	-	1	1
Nakina River[b]	5	13	3	-	-	1
Inklin River	-	-	1	1	-	2
Kowatua River	1	3	2	4	1	11
Nahlin River	-	1	-	-	-	-
Tatsatua Creek	-	-	1	1	-	3
Weekly total	8	21	11	10	5	23

Area	7/27-8/2	8/3-9	8/10-16	8/17-9/6	Total for area
Main stem (U.S.)	3	-	1	1	12
Main stem (Canada)	11	12	5	-	44
Nakina River (lower)[a]	1	-	1	-	5
Nakina River[b]	1	-	-	-	23
Inklin River	-	-	-	-	4
Kowatua Creek	8	3	-	-	33
Nahlin River	1	-	-	-	22
Tatsatua Creek	6	9	6	-	26
Weekly total	31	24	13	1	149

[a]Portion of river below the confluence with the Sloko River.
[b]Includes fish destined for the Silver Salmon and Sloko Rivers which are tributaries of the Nakina River.

Taku River from June 29 to August 16, 1986, which was comparable to the 98,277 fish estimated by McGregor and Clark (1987) for the same period. These results show that the sockeye salmon run on the Taku River was substantially smaller (21%) in 1986 than in 1984. Population estimates are summarized by discrete weeks of the run for 1984 and 1986 (Figs. 4, 5).

Four major in-river stocks were identified: main stem, Nakina River (lower and upper), Kowatua Creek, and Tatsatua Creek. Three minor stocks were also identified: Inklin River, Nahlin River, and Hackett River. In order to estimate the numbers of fish returning to these areas, based on the distribution of radio-tagged fish, it was necessary to tag over the course of the run in proportion to the number of fish present. Since the actual in-river abundance was unknown when the fish were being tagged, distribution information for the radio-tagged fish was analyzed for each week of the run using the bootstrap re-sampling technique.

Escapement estimates were calculated for the stocks of sockeye salmon returning to the Taku River (Figs. 6, 7). In 1986, main stem and Kowatua Creek stocks were most abundant. Problems inherent in sampling with fish wheels and mark/recapture estimates may bias these estimates. However, the additional information available suggests that the estimates obtained for the different stocks were reasonably close to actual numbers. A large proportion of the radio-tagged fish remained on the main stem, which corresponds to the large escapement estimate for this area. The fact that this result was observed in 1984 and 1986,

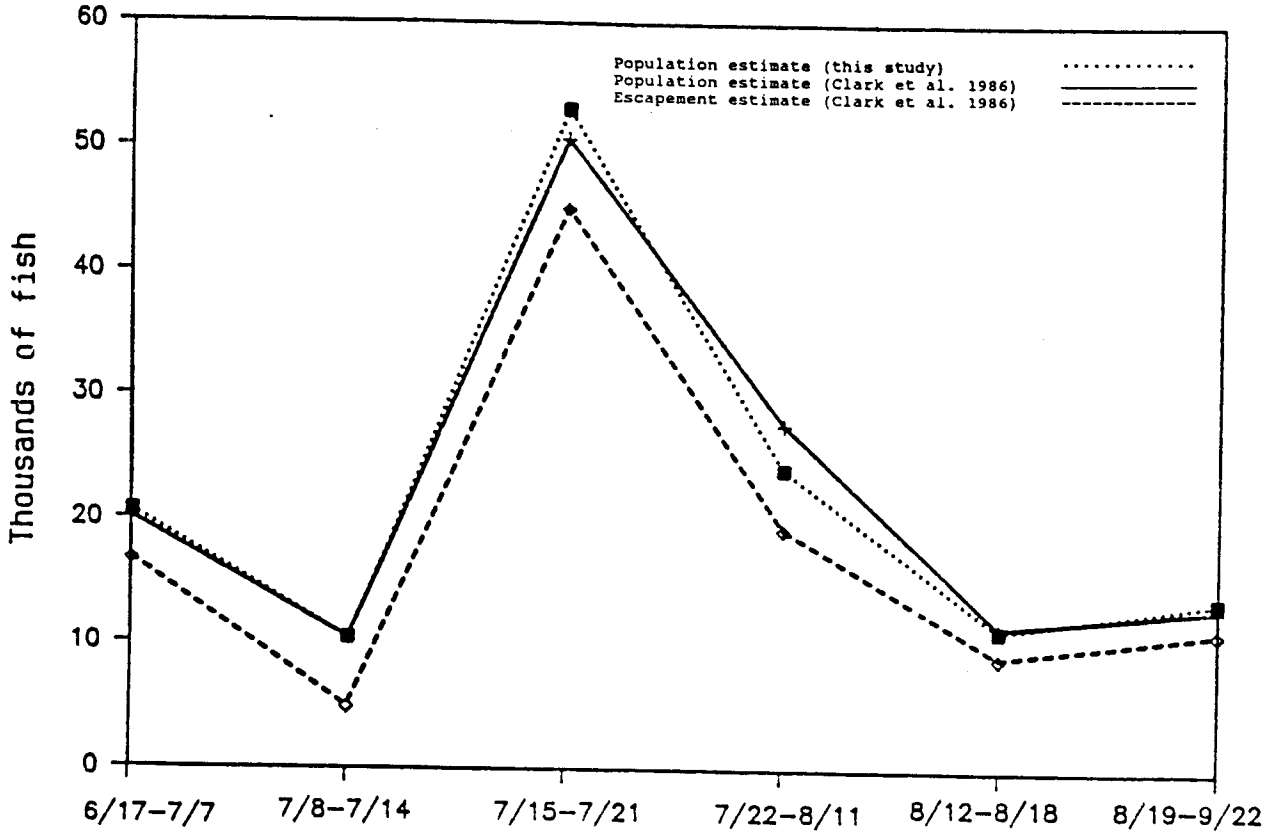

Figure 4.--Population and escapement estimates for adult sockeye salmon returning to the Taku River in 1984.

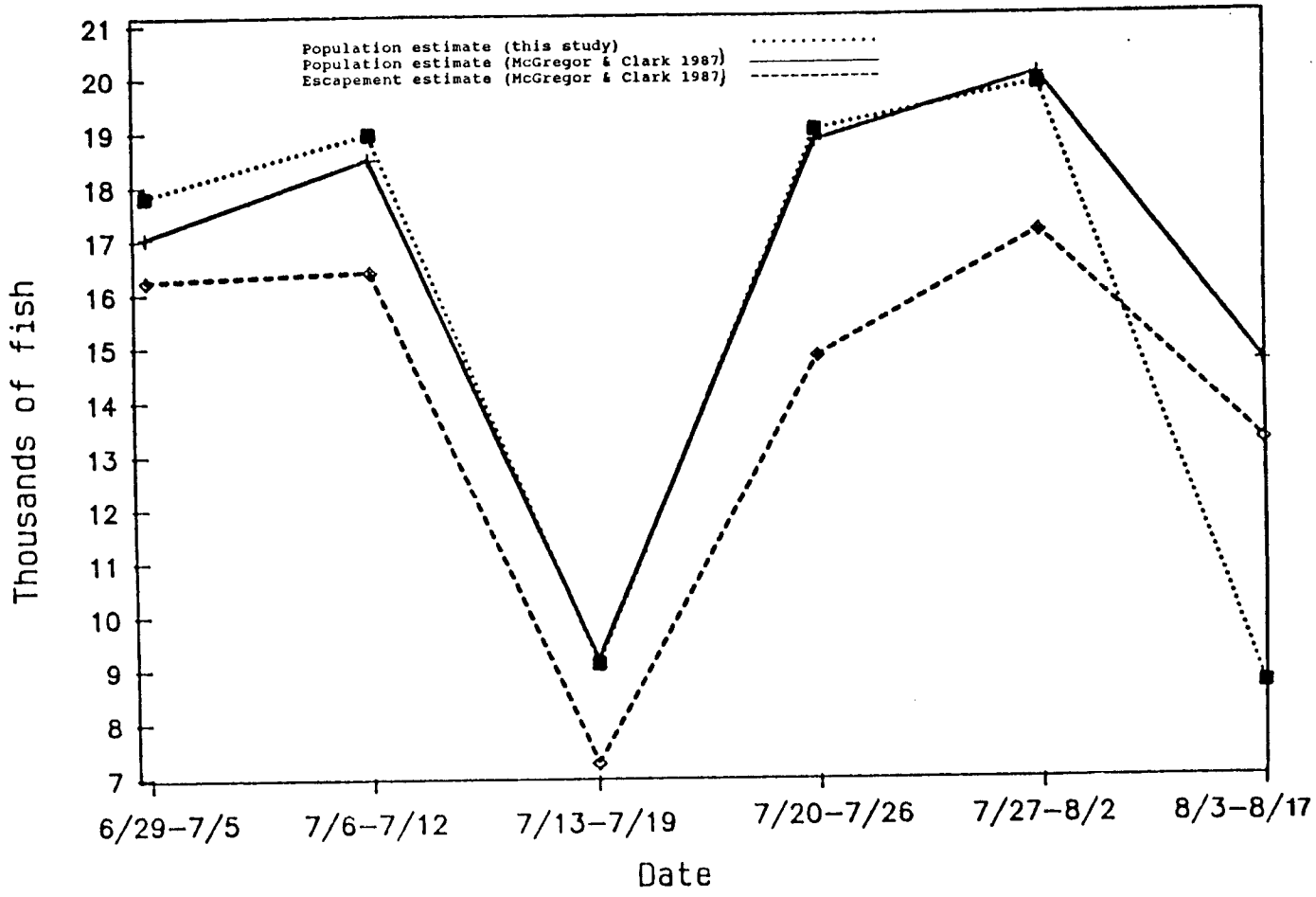

Figure 5.--Population and escapement estimates for adult sockeye salmon returning to the Taku River in 1986.

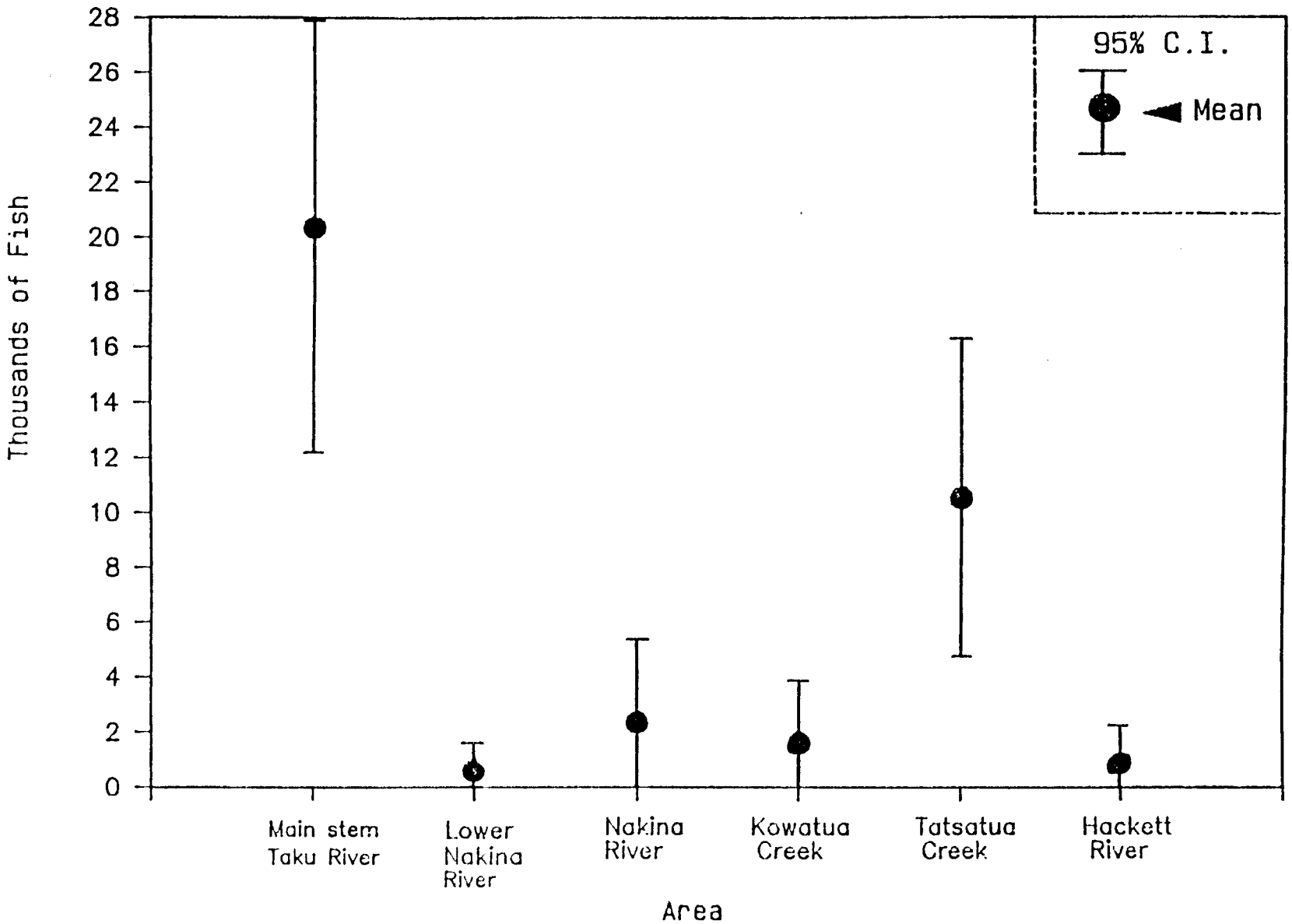

Figure 6.--Escapement estimates for adult sockeye salmon returning to different areas of the Taku River system during the last third of the run in 1984.

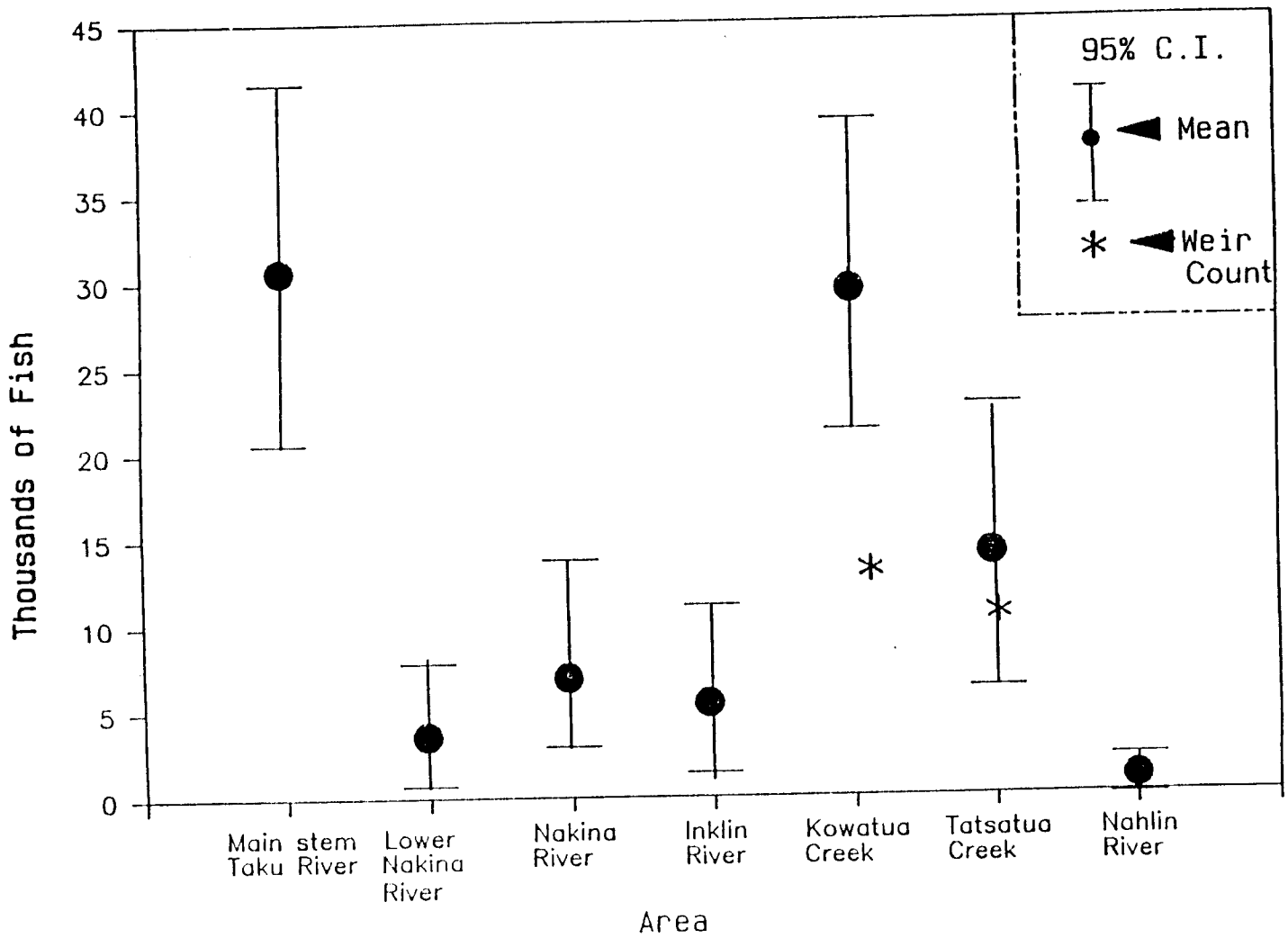

Figure 7.--Escapement estimates for adult sockeye salmon returning to different areas of the Taku River system in 1986.

and that the sample in 1986 was relatively large, makes it unlikely that this is a result of sampling error. Our estimate for the Nahlin River was 727 fish; Kissner (ADF&G Sport Fish Division, Juneau, Alaska, pers. comm.) estimates that only 300-1000 sockeye salmon spawn in the Nahlin River based on aerial surveys. Counting weirs were operated on Kowatua Creek and Tatsatua Creek during 1986, providing a check for the population estimates obtained for these areas. Our estimate for Tatsatua Creek was comparable to the actual weir count (Fig. 7). However, our estimate for Kowatua Creek was substantially higher than the weir count (Fig. 7).

The weir on Kowatua Creek is located at the outlet of Little Trapper Lake (Fig. 1). Only 22 (67%) of the radio-tagged fish that returned to Kowatua Creek passed through the weir, which corresponds to 17,169 of the estimated 25,625 fish that returned to this area. This estimate (17,169 sockeye salmon) is comparable to the weir count (13,820 sockeye salmon) at Little Trapper Lake in 1986. Although the estimate is somewhat higher than the weir count, there are indications that the weir counts may underestimate the number of fish entering the lake. Water levels and turbidity at the weir are sometimes high (Milligan, DF&O, Whitehorse, Yukon, pers. comm.), which may result in some fish not being counted. Only 8 (36%) of the radio-tagged fish that entered Little Trapper Lake were observed at the weir, although these fish were marked externally with gray spaghetti tags which might have been difficult to see. However, all of the radio-tagged fish that passed through the weir on Tatsatua Creek

were reported. Water levels and turbidity were relatively low at the weir site on Tatsatua Creek.

Three (9%) of the radio-tagged fish returning to Kowatua Creek, representing about 2,300 fish, spawned 1-3 km below the weir. Milligan (DF&O, Whitehorse, Yukon, pers. comm.) estimated that several hundred sockeye salmon spawn below the weir based on foot surveys of this area. Eight (24%) radio-tagged fish remained in an area 25-30 km downstream from the weir. Although it is possible that spawning occurs in this area, there are indications that a partial barrier may be restricting upstream movement. Kissner (ADF&G, Sport Fish Division, Juneau, Alaska, pers. comm.) observed brown bears catching fish in the same area directly below a rocky, constricted section of the creek. This section of the creek may act as a barrier to fish passage during certain periods, and fish holding below this area may be more susceptible to predation.

Population estimates for 1986 (Fig. 5) represent the in-river abundance of fish passing through the Canadian fishery after June 28. However, sockeye salmon were migrating through this area prior to this date. Twenty-eight (20%) of 137 radio-tagged fish were tagged before June 29. Nineteen (68%) of these fish were destined for the Nakina River, indicating that the population estimate for this area (Fig. 7) was underestimated.

Escapement estimates for Taku River stocks in 1984 were underestimated, since only the last one-third of the sockeye salmon run was sampled. Substantial numbers of fish returned to main stem areas (Fig. 6), supporting information from 1986 that

the main stem is an important spawning area. The large number of fish returning to Tatsatua Creek suggests that a major component of this stock returns during the latter portion of the run. Only a small number of fish returned to the Nakina River and Kowatua Creek, indicating that most fish destined for these areas return during the first two-thirds of the run.

It is not known how many sockeye salmon spawn on the U.S. portion of the Taku River, but this component is estimated to be around 5% of the total run (ADF&G, Commercial Fisheries Division, Juneau, Alaska, unpubl. manuscript). Twelve radio-tagged fish were tracked to areas below the U.S./Canadian border in 1986 (Table 4). A rough population estimate for sockeye salmon, based on the number of radio-tagged fish remaining in the U.S. is 7,000-8,000 fish, or approximately 5 to 6% of the total run.

Run Timing

Pronounced differences were observed in the run timing of different stocks on the Taku River, based on distribution information (Tables 3, 4) and weekly population estimates (Figs. 8a, 8b, 9a, 9b) for 1984 and 1986. However, confidence intervals for these estimates are wide, and the actual numbers may vary considerably for some weeks.

Nakina River sockeye salmon returned primarily during the early portion of the run. In 1986, 54% of the fish tagged with radio transmitters during the first 3 weeks of the study traveled to this area. The majority (79%) of Nakina River fish returned during the early portion of the run (mid- to late June) in 1986;

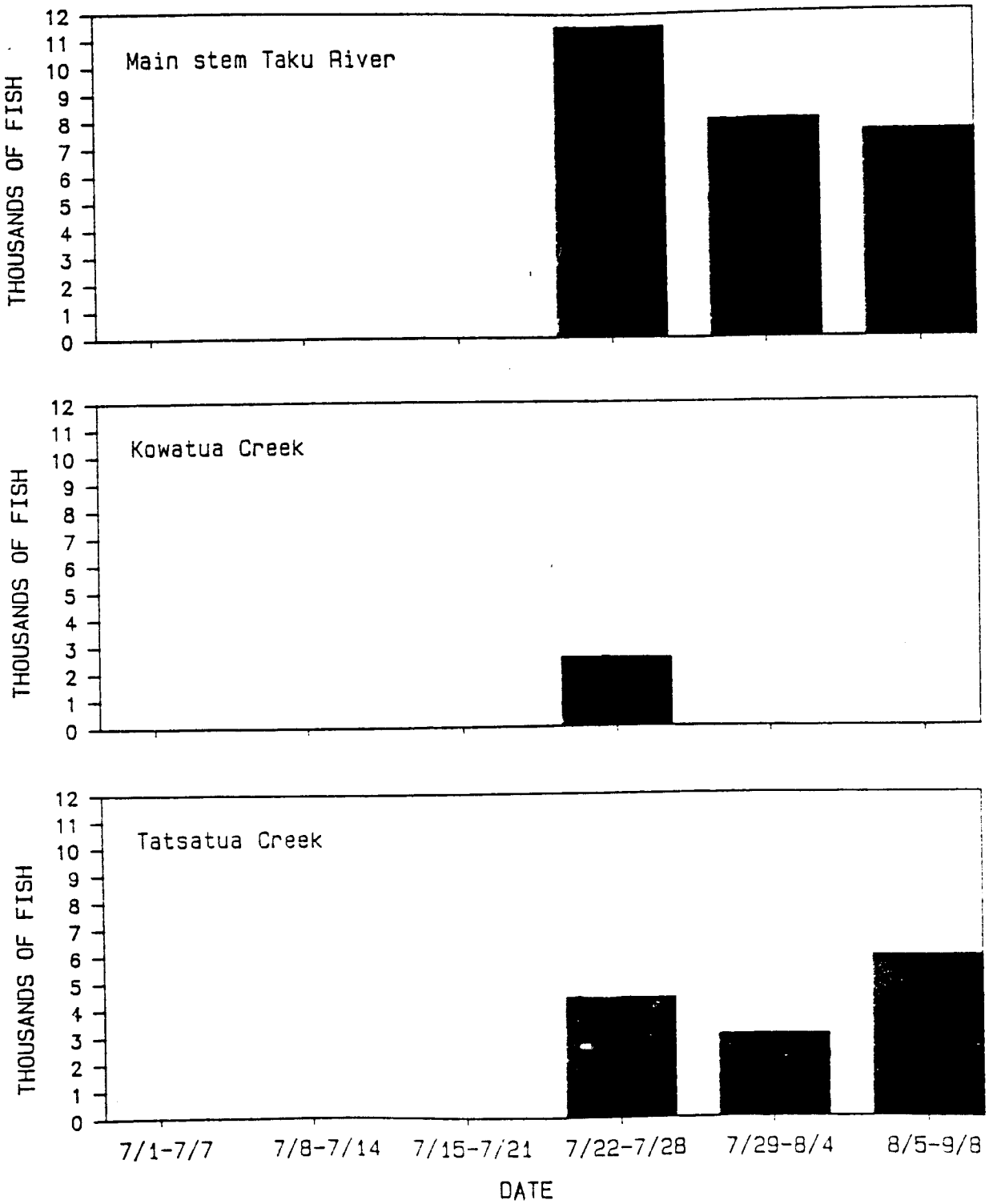

Figure 8a.--Run timing of sockeye salmon stocks returning to the Taku River during the last third of the run in 1984. Data are based on distribution information of radio-tagged fish and population estimates from mark/recapture studies.

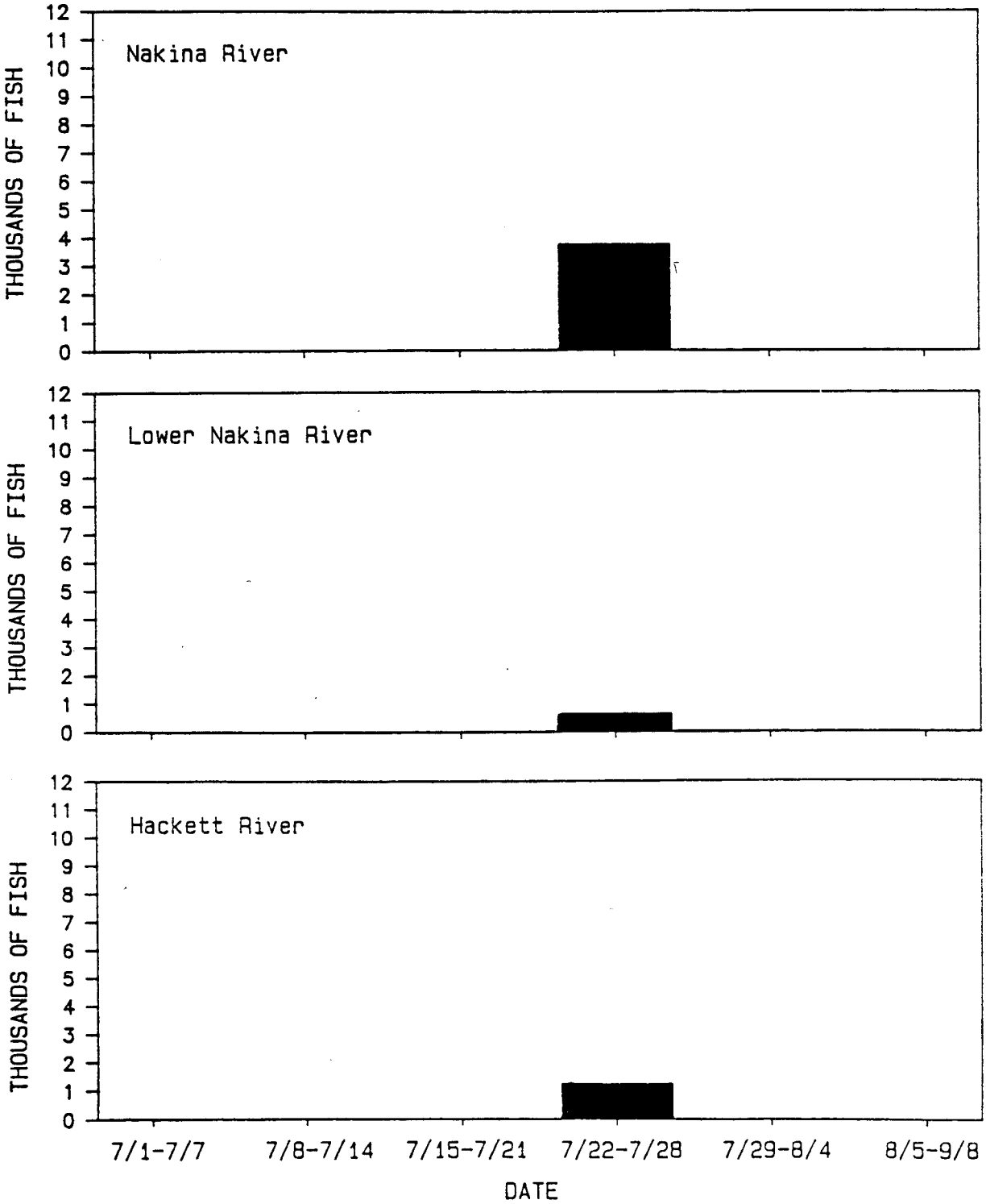

Figure 8b.--Run timing of sockeye salmon stocks returning to the Taku River during the last third of the run in 1984. Data are based on distribution information of radio-tagged fish and population estimates from mark/recapture studies.

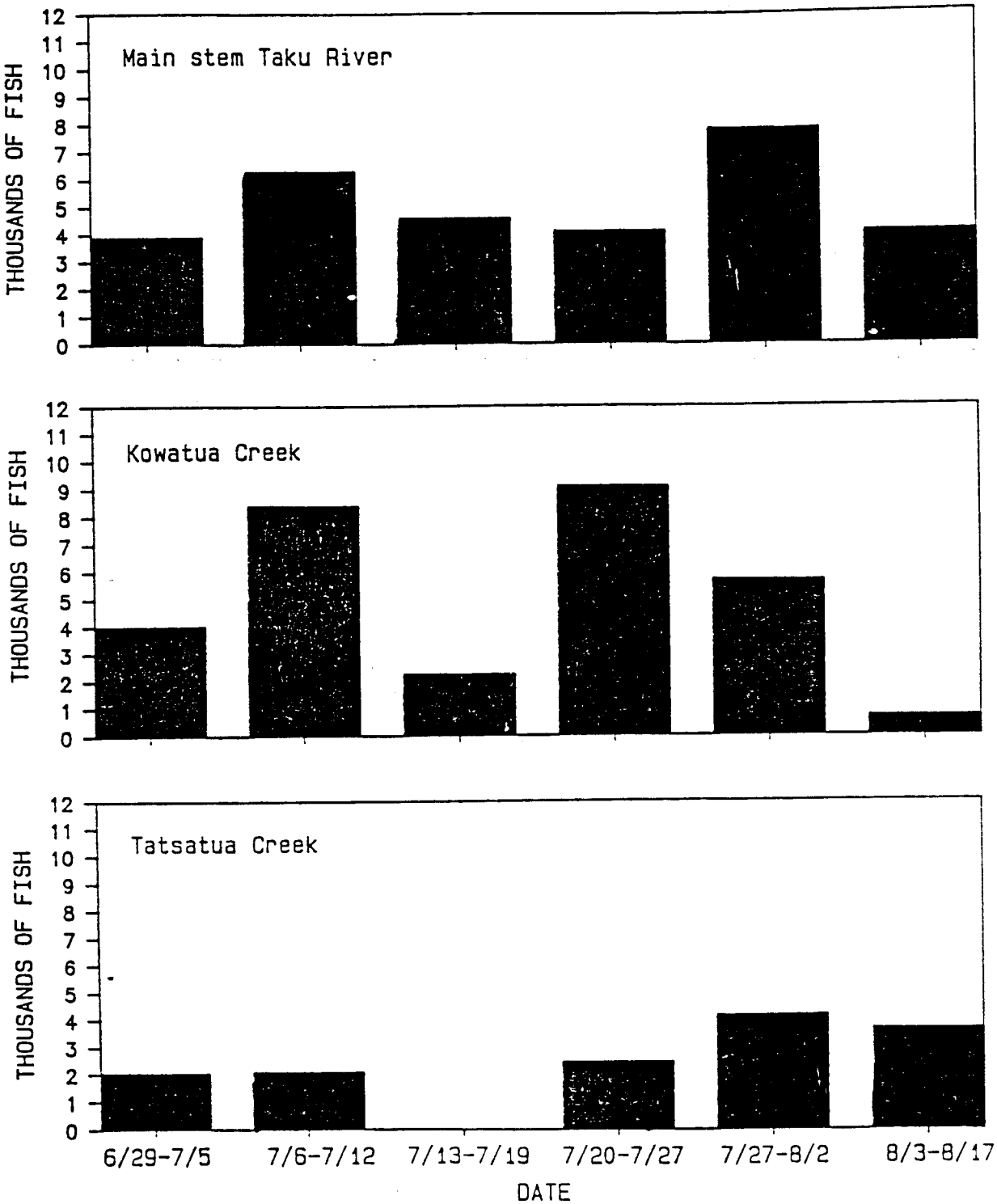

Figure 9a.--Run timing of sockeye salmon stocks returning to the Taku River in 1986 based on distribution information of radio-tagged fish and population estimates from mark/recapture studies. Fish entering the river in early June are not included due to lack of population estimates for this period.

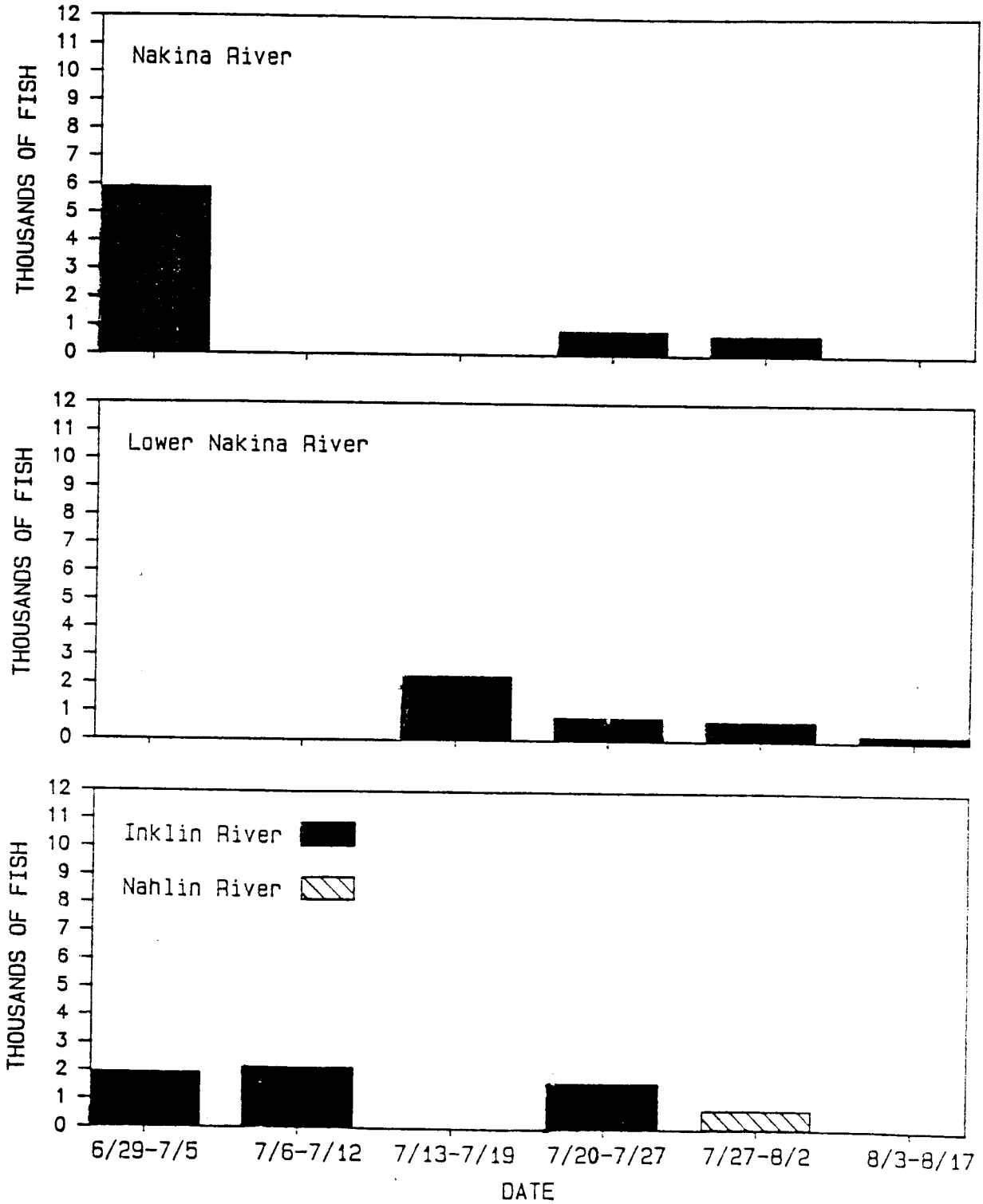

Figure 9b.--Run timing of sockeye salmon stocks returning to the Taku River in 1986 based on distribution information of radio-tagged fish and population estimates from mark/recapture studies. Fish entering the river in early June are not included due to lack of population estimates for this period.

only a small number arrived during mid July-early August (Table 4). A small number of sockeye salmon also returned to this area in late July of 1984 (Table 3, Fig. 8b). Most of the fish destined for the lower portion of the Nakina River returned during mid-July and early August.

Main-stem fish were present throughout the run, exhibiting a bi-modal distribution with the greatest peak during the latter portion of the run. A similar pattern was exhibited by fish destined for Kowatua and Tatsatua Creeks, although Kowatua fish were less abundant during the last part of the run. The Kowatua Creek stock appeared to peak earlier in 1984, since few sockeye salmon destined for this area were present after late July of that year.

Sockeye salmon destined for the Inklin River returned during the early portion of the run. Samples are too small to comment on run timing for sockeye salmon destined for the Nahlin and Hackett Rivers. Spaghetti-tag recoveries suggest that Hackett River fish are part of the mid to late part of the run.

Spawning Areas

Sockeye salmon spawning sites were located in six major areas: the main stem Taku River, Nakina River, Kowatua Creek, Tatsatua Creek, Hackett River, and the Nahlin River. Spawning by sockeye salmon on the main stem was widespread and occurred in many areas not normally associated with this species (Fig. 10). Sockeye salmon on the Nakina River used several main channel areas for spawning (Fig. 11). Physical barriers prevent fish

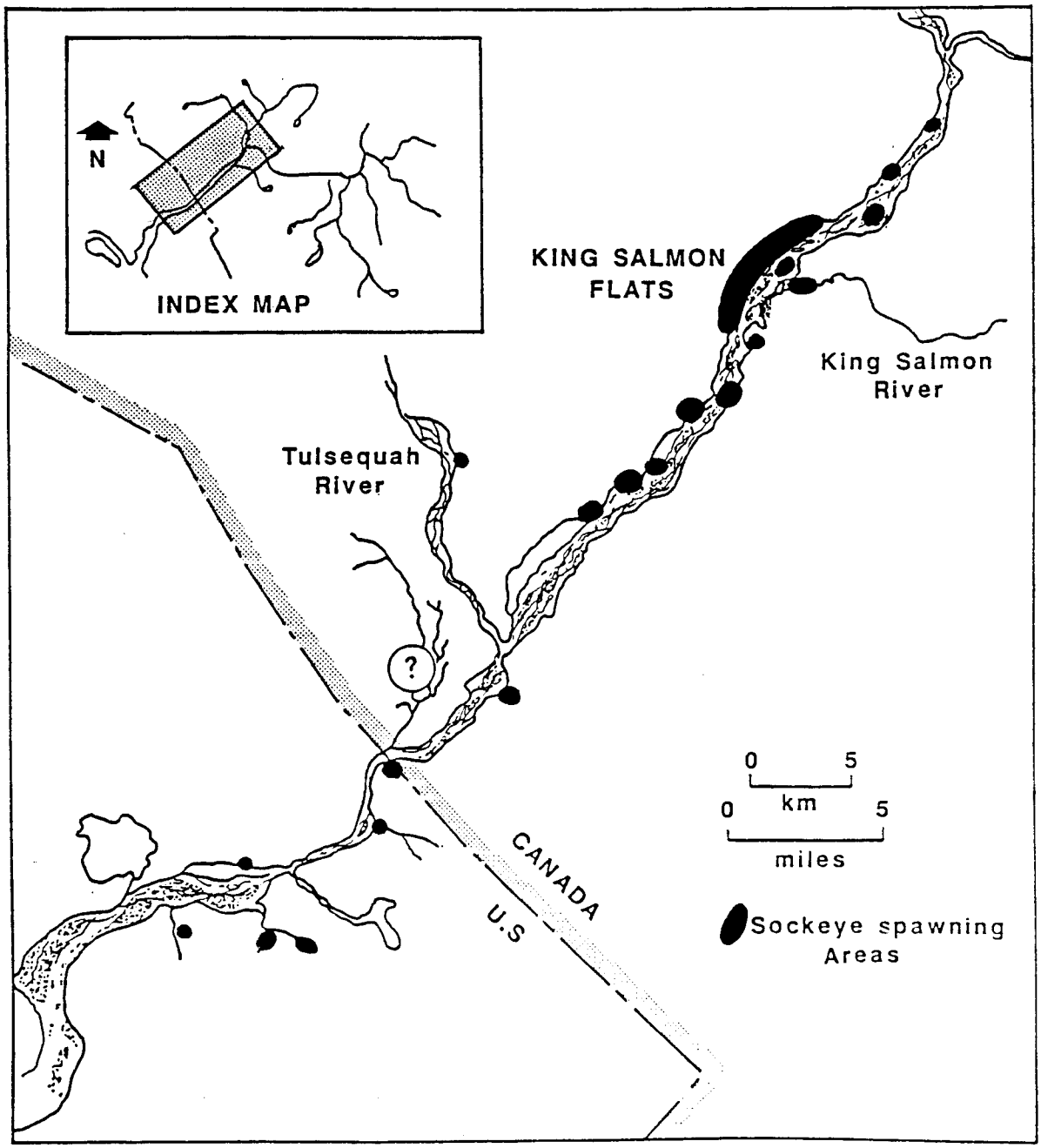

Figure 10.--Sockeye salmon spawning areas located on the main stem Taku River in 1984 and 1986.

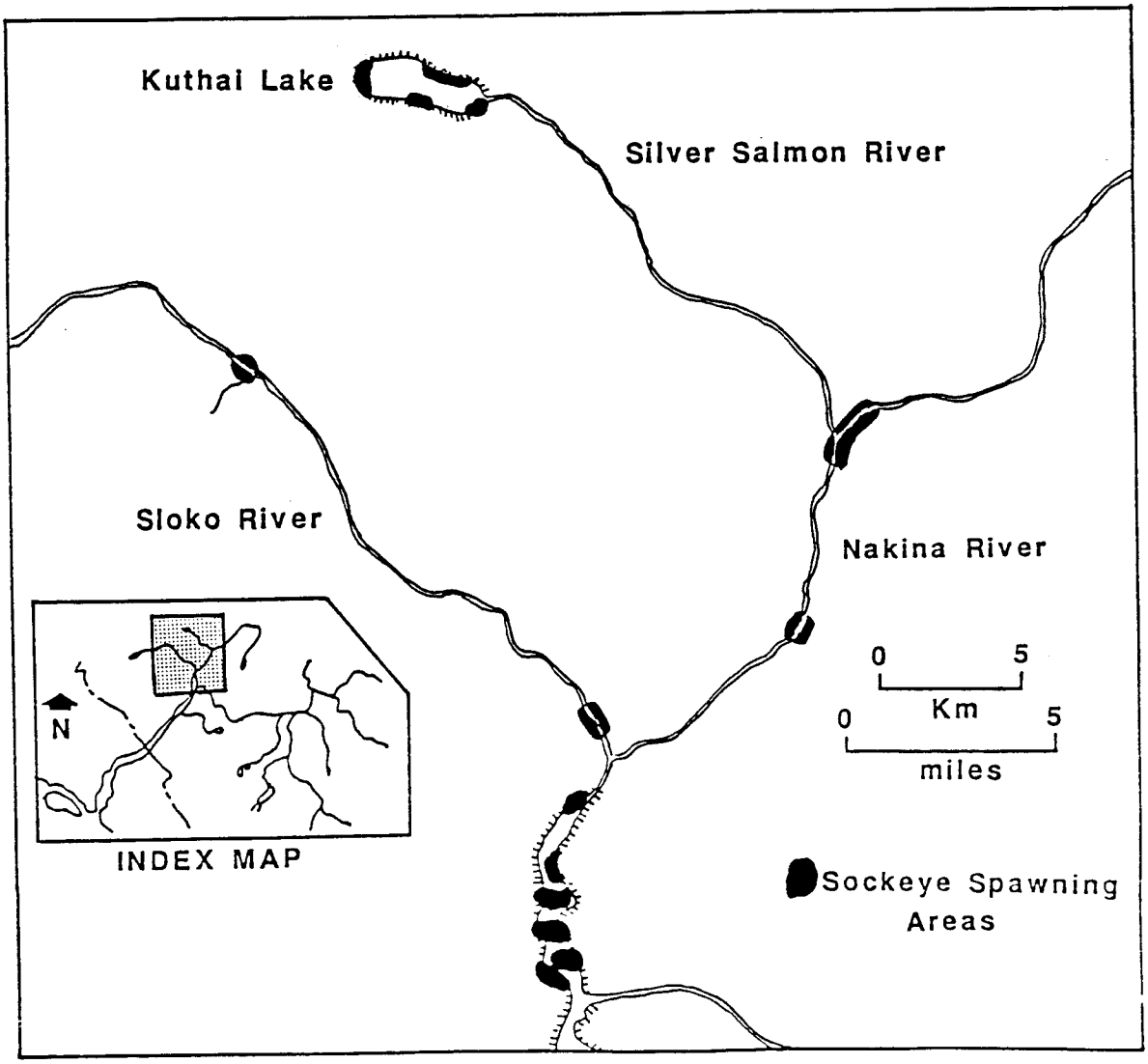

Figure 11.--Sockeye salmon spawning areas located on the Nakina River in 1984 and 1986.

from accessing Nakina and Sloko Lakes. A partial barrier sometimes prevents sockeye salmon from moving upstream to Kuthai Lake (ADF&G 1958). Spawning areas on Kowatua and Tatsatua Creeks were located near lakes on the systems (Figs. 12, 13). A physical barrier prevents fish from gaining access to Trapper Lake on Kowatua Creek. Spawning sockeye salmon were observed along the entire length of the Hackett River with intensive spawning in some areas (Fig. 14). Spawning areas on the Nahlin River were restricted to a small section of the main river (Fig. 15). Kissner (ADF&G, Sport Fish Division, Juneau, Alaska, pers. comm.) reported that aerial surveys of the Nahlin River have not located any other spawning areas on this portion of the system. The spawning habitats used by sockeye salmon in the different portions of the Taku River system were diverse (Table 5).

Actual spawning areas were not observed on the Inklin River due to turbid water conditions. The radio-tagged fish were located in an area of the river with side channels, but it was not determined if the fish were spawning or holding in this area prior to moving to actual spawning sites.

Main Stem Utilization

Prior to 1984, it was believed that most of the sockeye salmon returning to the Taku River spawned in lake systems in the upper portion of the drainage. Sixty to 70% of the sockeye salmon returning to the Taku River were thought to spawn in areas around Little Trapper Lake (Fig. 1; Ingledue 1977). Our study showed that a substantial proportion of the sockeye salmon

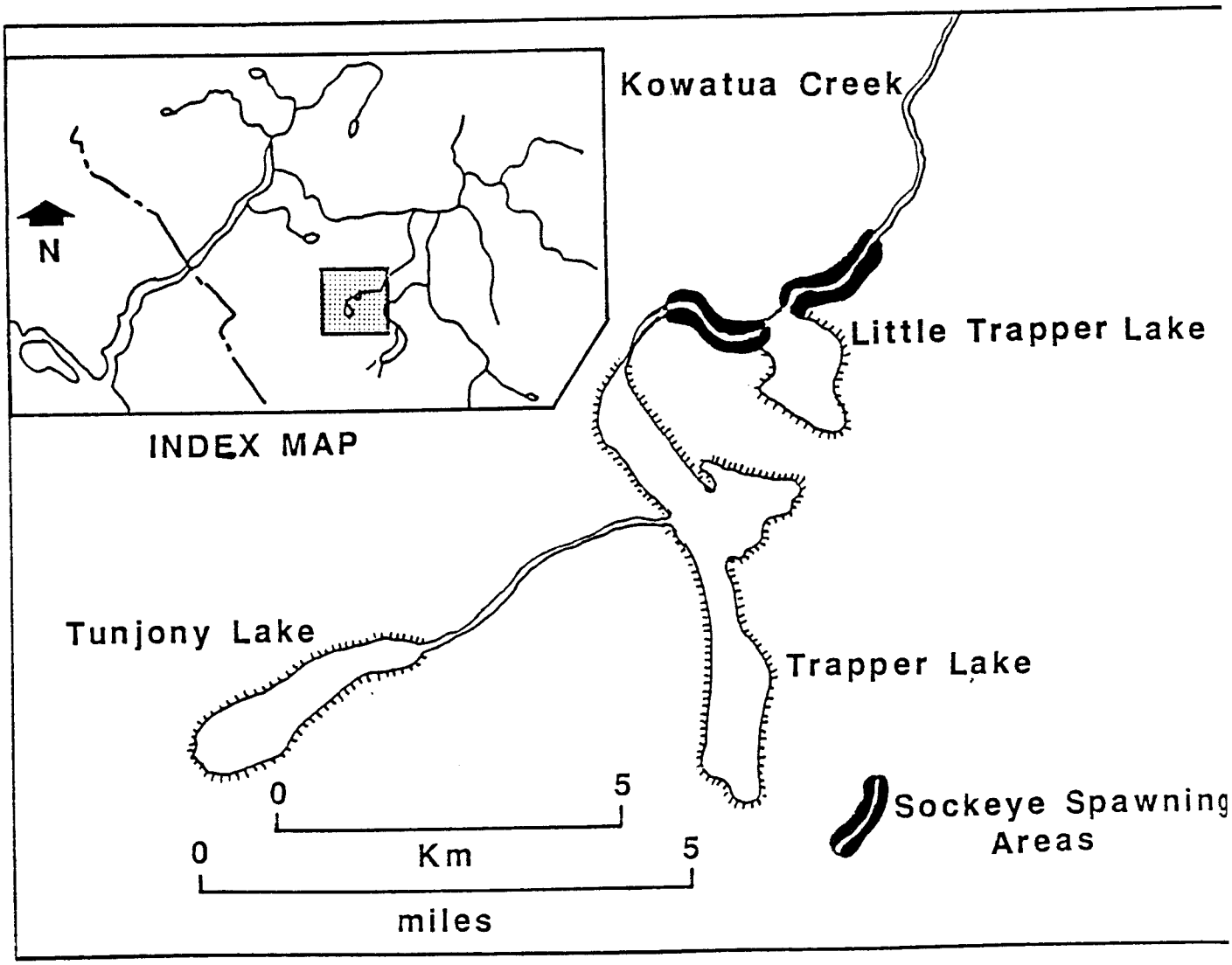

Figure 12.--Sockeye salmon spawning areas located on Kowatua Creek in 1984 and 1986.

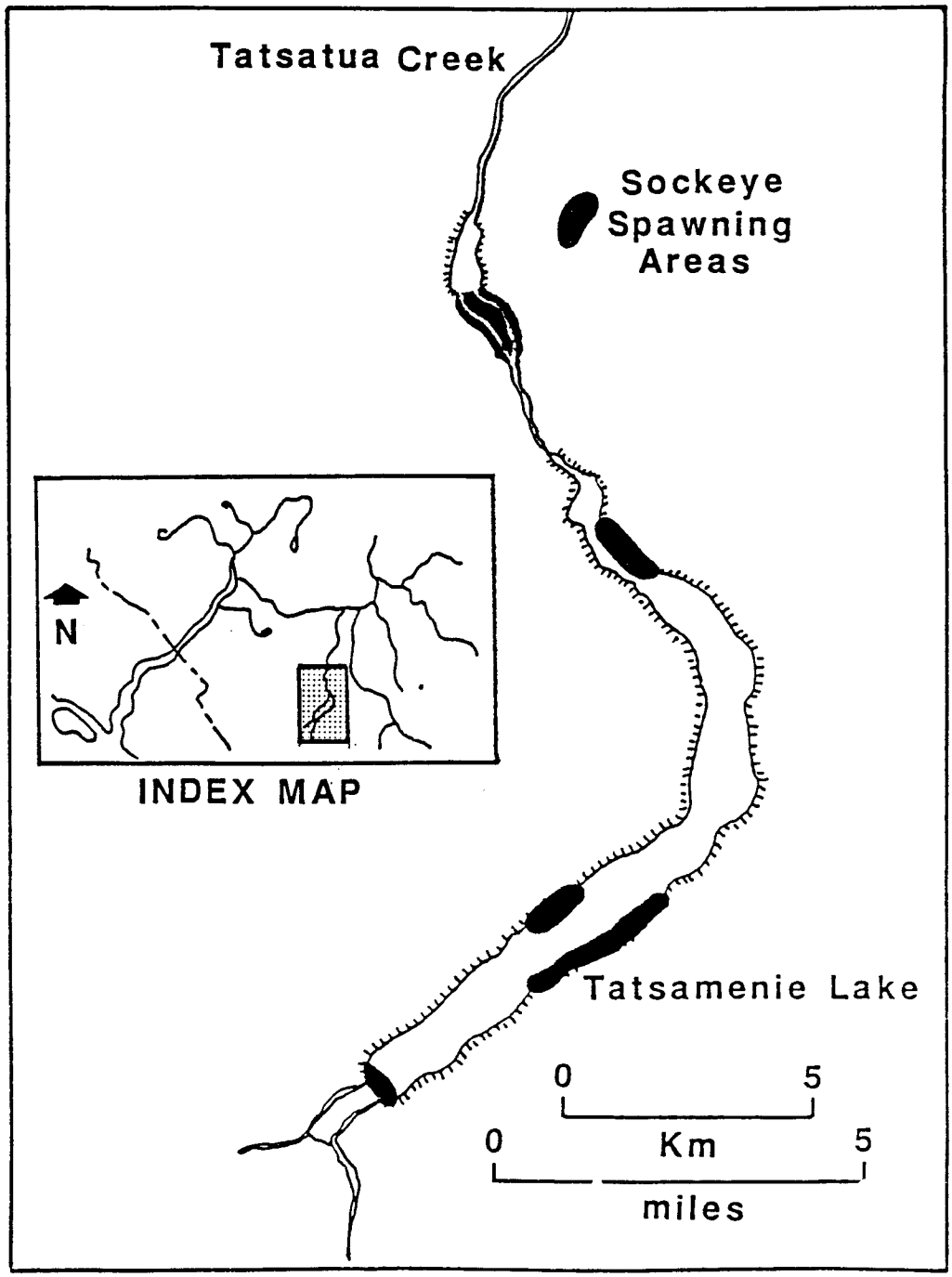

Figure 13.--Sockeye salmon spawning areas located on Tatsatua Creek in 1984 and 1986.

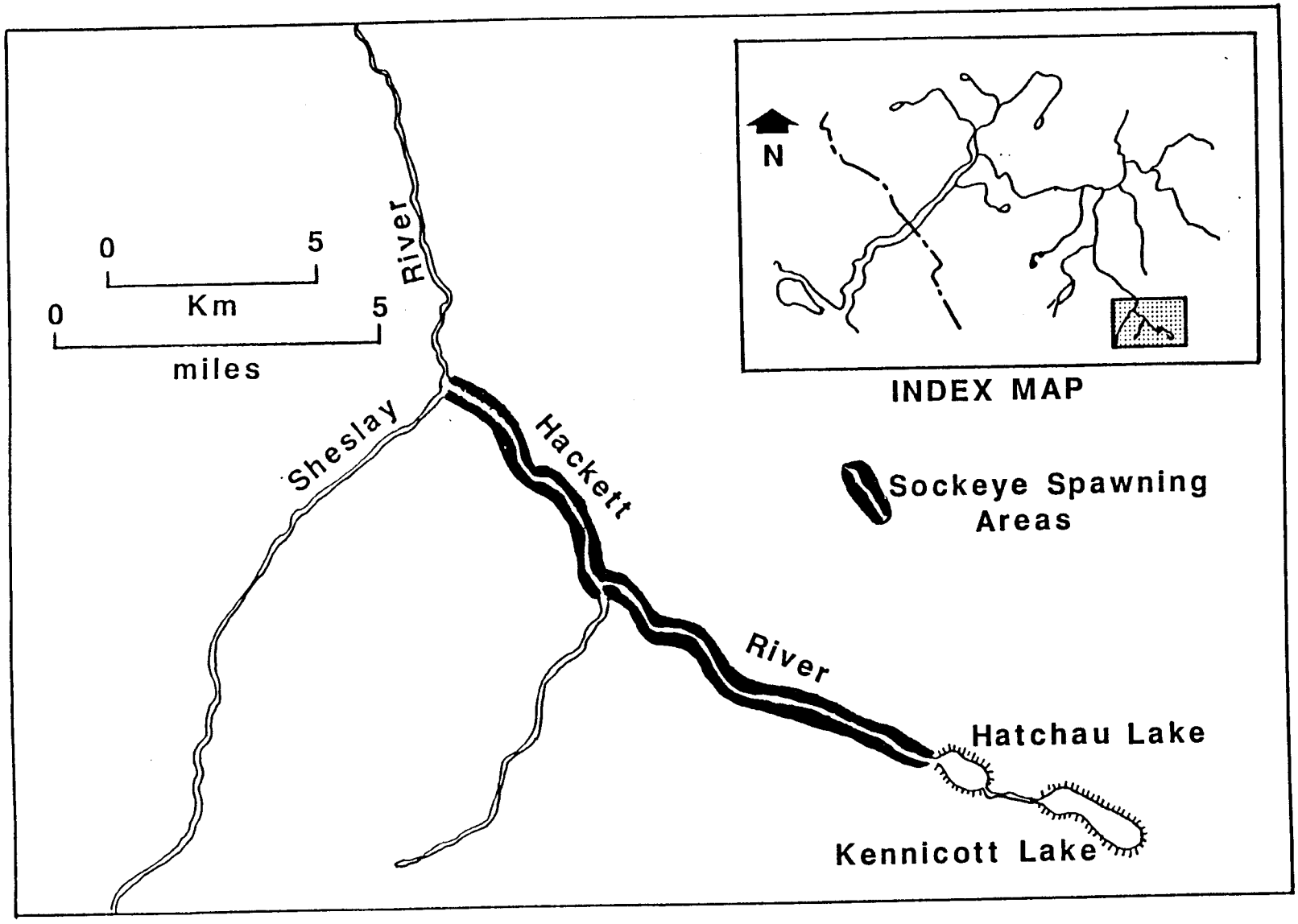

Figure 14.--Sockeye salmon spawning areas located on the Hackett River in 1984 and 1986.

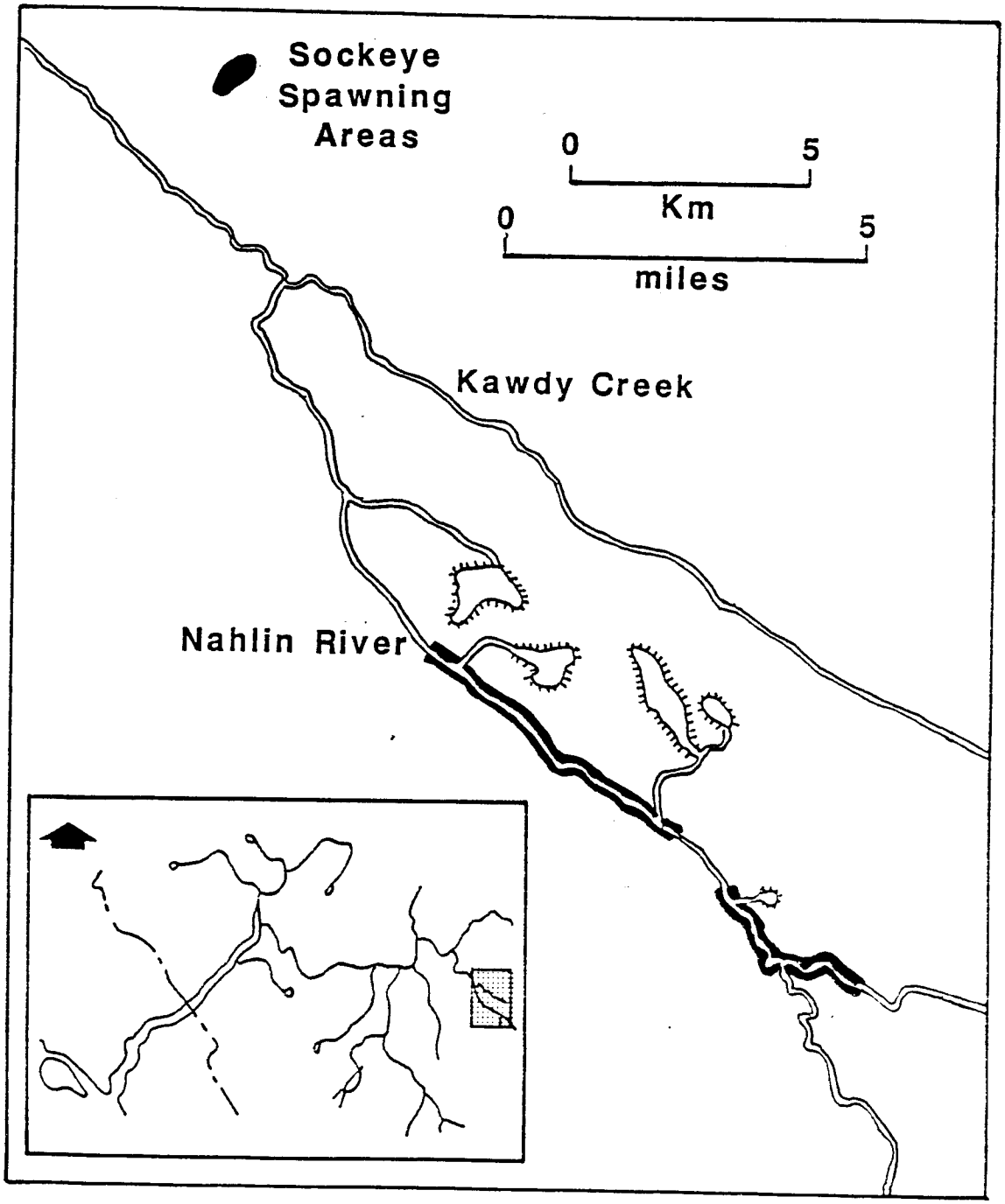

Figure 15.--Sockeye salmon spawning areas located on the Nahlin River in 1984 and 1986.

Table 5.--Spawning habitat used by adult sockeye salmon the Taku River, 1984 and 1986.

Area	Habitat type
Main stem Taku River	Main channel Side channel Tributary mouth Tributary Upland slough Upwelling basin Lake system
Nakina River (lower)[a]	Main channel Side channel
Nakina River	Main channel Side channel[b] Tributary[b] Lake: Shoreline[b]
Kowatua Creek	Lake: Inlet creek Outlet creek
Tatsatua Creek	Lake: Inlet creek Outlet creek Shoreline
Hackett River	Main channel Upland slough Tributary
Nahlin River	Main channel

[a]Portion of river below the confluence with the Sloko River.
[b]Areas on tributaries of the Nakina River.

returning to the Taku River spawn in the main stem. The fact that large numbers of sockeye salmon spawn in areas not previously identified or considered suitable for this species has significant management implications.

A comparison of escapement estimates for the entire Taku River with non-main stem areas (from weir counts and aerial surveys

of clear upriver areas) supports our belief that large numbers of sockeye salmon spawn in the main stem. Escapement estimates of sockeye salmon on the Taku River from 1984-86 average about 100,000 fish (Canada/U.S. Transboundary River Technical Committee 1987). Weir counts of sockeye salmon for Kowatua Creek, Tatsatua Creek, and the Hackett River average just over 28,000 fish. Kissner (ADF&G, Sport Fish Division, Juneau, Alaska, pers. comm.) estimated that less than 10,000 fish and only 300-1000 fish spawn on the Nakina and Nahlin Rivers, respectively. These areas combined account for only 40,000 fish or approximately 40% of the estimated run. Except for a small number of fish that return to the lower Nakina and Inklin Rivers, telemetry data indicates that no other major spawning areas are present on the Taku River system. These results suggest that 50-60% of the run (50,000 to 60,000 fish) spawn in the main stem. Therefore, we believe our escapement estimate for the main stem is reasonable, and may underestimate actual abundance for this area.

A low estimate for the number of sockeye salmon using the main stem, based on the distribution of radio-tagged fish, may be a function of our analysis. Predation on the main stem is heavy, and many fish using side channels are killed by predators. Many radio-tagged fish killed by predators on the main stem were not included in the analysis because it was impossible to determine whether they were main stem fish or other stocks holding in main stem areas before moving upriver. It is likely that most were main stem fish, since fish attempting to spawn in an area would probably be more susceptible to predation than fish holding in an

area before continuing their upriver migration. This would result in the proportion of main stem fish being under represented. When these fish were included in the sample, the escapement estimate for the main stem was over 40,000 fish.

Although we believe that substantial numbers of fish utilize main stem areas, and that our population estimates of about 30,000 fish may be low, it is also possible that the population estimates calculated for the run (Clark et al. 1986; McGregor and Clark 1987) and used to estimate escapement for the component stocks are too high. Lower population estimates would result in lower escapement estimates for the component stocks.

Sockeye salmon returning to lake systems spend some time in the lakes before moving to spawning areas (Foerster 1968). Taku River main stem fish appear to exhibit the same type of pattern, except that they use river channels instead of lakes. Radio-tagged fish remained in main channel areas of the main stem for prolonged periods prior to moving to their spawning grounds. Telemetry data and weekly surveys of clearwater spawning areas on the main stem suggest that groups of sockeye salmon move on to spawning grounds throughout the spawning period. Spawning on the main stem occurs from late August to early October. Fish moving on to the spawning grounds throughout this period could account for large numbers of fish.

Spawning was not evenly distributed on the main stem; some areas were used more extensively than others. For example, King Salmon Flats (Fig. 10) was an important spawning area. Almost 30% of the radio-tagged fish located on the main stem spawned in

this locale. Management of the river should attempt to protect King Salmon Flats from other uses that might have a negative impact because of the importance of this area for spawning.

Although many of the spawning areas used on the main stem were turbid from glacial silt, we were able to document spawning and locate redd sites when low water levels allowed direct observations. This occurred during September 1986 when normally turbid side channels and main channel edges cleared as a result of unusually low water levels and several weeks without precipitation.

Sockeye salmon on the main stem spawned in areas not typically used by this species. Sockeye salmon usually select spawning areas closely associated with lake systems (Foerster 1968). Fifty-four percent of the radio-tagged fish on the main stem spawned in side channels (Table 6), often in the same areas used by chum salmon (O. keta). Small tributaries flowing into the main stem, tributary mouths, upland sloughs, upwelling basins and a lake (associated with a main stem tributary) were also used by sockeye salmon spawning on the main stem.

It was not possible to observe fish in some upland sloughs due to discolored water, although we assumed these areas were used for spawning due to the number of radio-tagged fish that remained in these areas during the fall. A number of radio-tagged fish also remained in main channel areas late into the fall. We were unable to determine if these fish were spawning or holding in these areas prior to moving to their spawning grounds.

Table 6.--Spawning habitat on the main stem Taku River used by adult sockeye salmon tagged with radio transmitters, 1984 and 1986.

Habitat type	Total	1984	1986
Side channel	31 (54%)	11 (46%)	20 (61%)
Tributary mouth	1 (2%)	1 (4%)	-
Tributary	8 (14%)	1 (4%)	7 (21%)
Upland slough	7 (12%)	5 (21%)	2 (6%)
Upwelling basin	9 (16%)	6 (25%)	3 (9%)
Lake	1 (2%)	-	1 (3%)
Total	57	24	33

Selection of spawning sites within side channels was not random, but concentrated in certain areas. Limited work in 1984 suggested that spawning in these areas was associated with upwelling water. Intensive sampling in 1986 (Lorenz and Eiler, NMFS, Auke Bay, Alaska, in prep.) verified this relationship.

One reason the main stem was considered unsuitable for sockeye salmon was an assumed lack of rearing habitat. Juvenile sockeye salmon normally rear in lake systems for 1 to 2 y before migrating to sea. Sockeye salmon on the main stem apparently have adapted survival strategies that compensate for the lack of typical rearing areas. Murphy et al. (unpubl. manuscr.) reported that juvenile sockeye salmon on the Taku River used alternative types of habitat in the absence of typical rearing areas on the main stem. In addition, the growth patterns of scales collected

from returning adult sockeye salmon on main stem spawning grounds showed that over 48% of the sockeye salmon using main stem areas in 1986 migrated to saltwater during the first year of life (Table 7), minimizing the need for extensive rearing areas.

The occurrence of freshwater age-0 fish on the main stem was most evident in locales without suitable rearing areas, such as side channels and upwelling basins. Juvenile sockeye salmon rear in the numerous beaver ponds and sloughs associated with Yehring Creek (Murphy et al. 1988) and the percentage of freshwater age-0 fish in this area is significantly less than main channel areas (Table 8). Sockeye salmon returning to lakes in the upper portion of the drainage had the lowest percentage of freshwater age-0 fish.

Table 7.--Freshwater age of returning adult sockeye salmon for different spawning areas of the main stem Taku River, 1986. In parentheses is percent sampled fish by location and freshwater age; N = sample size.[a]

Location	No. fish by freshwater age			
	0	1	2	N
U.S. Section[b]	6 (6)	96 (90)	4 (4)	106
Lower Canadian[c]	35 (55)	28 (45)		62
Middle Canadian[d]	194 (64)	104 (34)	4 (2)	304
Upper Canadian[e]	10 (24)	29 (71)	2 (5)	41
Total	246	257	10	513

[a]Scale samples aged by the Alaska Department of Fish and Game.
[b]Tributaries of the main stem.
[c]Upwelling basin near U.S./Canada border.
[d]King Salmon Flats side channel complex.
[e]Lower Nakina River side channels.

Table 8.--Percent of returning adult sockeye salmon that are freshwater age-0 for different habitat types in the Taku River, 1986.[a] Numbers are in parentheses.

Habitat	Area	Age-0	Total
Lakes	Kuthai Lake[b]	0 (0)	221
	Little Trapper Lake[b]	0.2 (1)	671
	Tatsamenie Lake[b]	1.8 (13)	723
Creek	Yehring Creek[c]	9.2 (17)	189
Rivers	Nakina River	37.7 (20)	62
	Hackett River[b]	39.0 (48)	124
Tributary mouth	Fish Creek[c]	42.0 (8)	19
Side channel	Shustahini[c]	51.6 (48)	93
	Honakta[c]	62.0 (31)	50
	Tuskwa[c]	68.7 (33)	48
Upwelling basin	South Fork Slough[c]	64.8 (35)	54
	Coffee Creek[c]	79.2 (19)	24
	Total	(273)	2,264

[a]Scale samples aged by the Alaska Department of Fish and Game.
[b]Samples collected by Alaska Department of Fish and Game and Canadian Department of Fisheries and Oceans.
[c]Areas associated with the Taku River main stem.

CONCLUSIONS

A substantial portion of the sockeye salmon returning to the Taku River utilize main stem areas for spawning. Spawning was widely distributed on the main stem, although several primary areas were located. The Nakina River, Kowatua Creek, and Tatsatua Creek were also important spawning areas for this species. Several areas of lesser importance were also identified.

Differences in run timing were observed for different stocks of Taku River sockeye salmon. Nakina River fish arrived primarily

during the early portion of the run before other stocks were prevalent. Main stem, Kowatua Creek, and Tatsatua Creek fish were present throughout the season, with peaks during the later portion of the run.

Sockeye salmon on the main stem used spawning areas not usually considered suitable for this species. The majority of fish spawned in side channels. Main stem sockeye salmon also used small tributaries, upland sloughs, upwelling basins, and lakes for spawning. Suitable spawning habitat in many areas may be limited to sites with upwelling water.

Sockeye salmon spawning on the main stem remained in main channel areas for prolonged periods of time before moving to the spawning sites. Groups of fish moved to the spawning grounds at different times throughout the period of spawning. This behavior may make it possible for large numbers of fish to spawn in main stem areas.

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