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Migrations of Juvenile Salmon in the Taku River, Southeast Alaska

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MIGRATIONS OF JUVENILE SALMON IN THE TAKU RIVER, SOUTHEAST ALASKA

by

Michael L. Murphy, K V. Koski,

J. Mitchel Lorenz, and John F. Thedinga

Auke Bay Laboratory

Northwest and Alaska Fisheries Center

National Marine Fisheries Service

National Oceanic and Atmospheric Administration

P.O. Box 210155, Auke Bay, Alaska 99821

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ABSTRACT

Migrations of juvenile salmon (Oncorhynchus spp.) in the Taku River, Southeast Alaska, were monitored by fyke-netting the river from April to November 1987 and by seining the estuary from April to September 1987. Chum (O. keta) fry (age 0; mean fork length (MFL), 42 mm), chinook (O. tshawytscha) smolts (98% age 1, 2% age 2; MFL, 76 mm), and sockeye salmon (O. nerka) smolts (100% age 1; MFL, 65 mm) migrated to sea in May and June; however, "sea-type" sockeye fry (age 0; MFL, 53 mm) migrated downstream from May to November and were caught in the estuary from June to September. Coho salmon (O. kisutch) smolts and parr (92% age 1; 8% age 2; MFL, 85 mm) migrated downstream in May and June, and smolts were in the estuary from May to August. Migrants appeared to use the lower river in May to grow and transform to smolts before going to sea. Many age-0 coho and chinook also moved downstream in summer and fall as the river level dropped, but were not caught in the estuary; these migrants probably reared and overwintered in the lower river.

CONTENTS

INTRODUCTION

The Taku River, flowing from British Columbia into Southeast Alaska, is important to both the United States and Canadian salmon (Oncorhynchus spp.) fisheries. Annual harvests include sockeye (O. nerka), chum (O. keta), chinook (O. tshawytscha), coho (O. kisutch), and pink (O. gorbuscha) salmon (Clark et al. 1986). Habitat utilization and carrying capacity of the river, however, are too poorly understood to efficiently manage the stocks for optimum production.

Recent research indicates that migratory behavior plays an important role in determining habitat utilization within the river. For example, the lower 20 km of river, between the U.S./Canada border and the estuary, is a summer nursery area for an estimated 1.2 million juvenile sockeye, coho, and chinook salmon (Murphy et al. in prep.), but because of limited spawning habitat (Eiler et al. 1988), most of these juveniles probably originate from spawning habitat upriver. Therefore, information on migration of juvenile salmon is needed to help assess habitat utilization and the river's carrying capacity. Further, data on seaward migrants can be used to measure smolt production, predict adult returns, and help establish escapement goals to maximize production from available habitat (Symons 1979).

Previous studies have shown prolonged downstream migration in the river (Meehan and Siniff 1961; Heifetz et al. 1987) but did not distinguish between migrants going to sea and those staying in the river; hence, seaward migrants and utilization of the lower river were not described. In this study, both downstream migration and estuarine rearing were monitored to determine the time, size, and age at which salmon migrate to sea, as well as when they migrate to and utilize the lower river.

STUDY AREA

The Taku River originates in British Columbia and empties into Taku Inlet 40 km northeast of Juneau, Alaska (Fig. 1). Much of the year the river is swift and turbid with glacial silt. The main river channel is about 5 m deep and 200 m wide. Discharge is low (<100 m^3/s) in winter when the river freezes over, and high (1,000 m^3/s) during snowmelt in June. Each summer, the lower river floods when ice dams on the Tulsequah River suddenly burst. The estuary is a narrow (1-6 km wide) fiord, extending 30 km from the mouth of Taku Inlet to the end of tide flats near Taku Lodge.

Five salmon species occur in the drainage. Sockeye is the most valuable species, with an annual adult return of about 200,000 (McPherson and McGregor 1986). The chinook (*O. tshawytscha*) fishery has been restricted since the 1970s because stocks have been depressed; recent adult returns are about 7,500 fish (Kissner 1984). Adult returns of coho (*O. kisutch*), chum (*O. keta*), and pink (*O. gorbuscha*) salmon are estimated at 40,000; 50,000; and 200,000 fish, respectively (Canada/U.S. Transboundary Technical Committee 1986).

METHODS

River Sampling

To monitor downstream movement of juvenile salmon, a fyke net was set in the lower river, 17 km upstream from the estuary (Fig. 1). The net opening of 13-mm mesh was 3 m wide by 1.5 m deep and

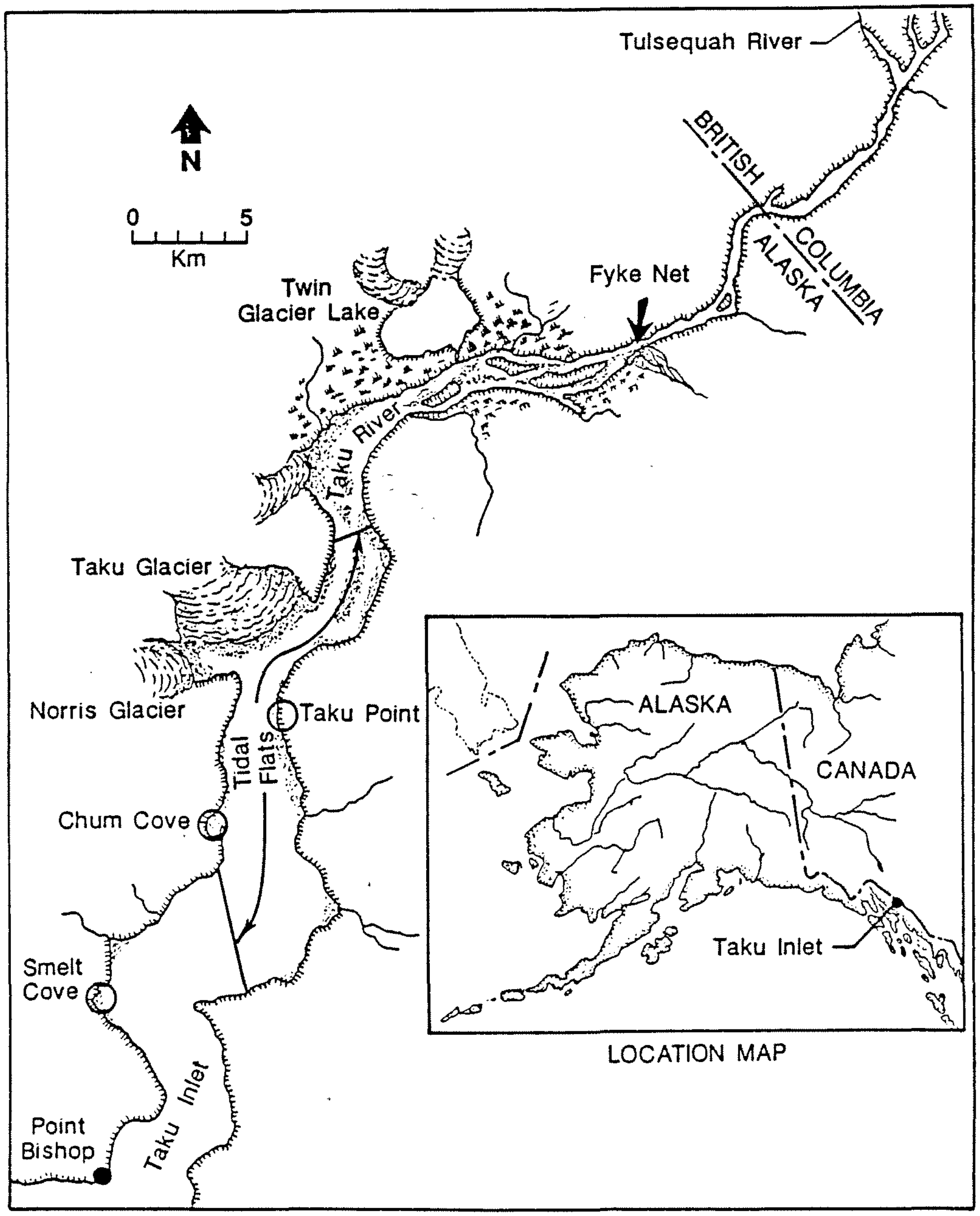

Fig. 1.--Location of the fyke net for catching downstream migrants in the Taku River, Alaska, and beach seining sites in the river's estuary.

funnelled into a cod end of 6-mm mesh that led to a floating live box. The net's total length was 15 m.

The net was set 4 m from shore perpendicular to the main river flow for 2-3 d each sampling period; sampling periods were every week from 22 April to 6 August and every 2-4 wk thereafter until 4 November. The top of the net was positioned just below the river surface to avoid floating debris yet sample the upper 1.5 m of river where most fish migrate (Meehan 1964). Depending on river stage, water was 1.5-5 m deep, and current speed averaged 67 cm/s. During each sampling period, the net was removed from the river and cleaned of debris every 1-23 h to prevent clogging the cod end; the mesh usually became coated with fine debris within a few hours.

Fish captured were anesthetized, identified to species, and counted. A random sample (up to 50 fish of each species and age class) was measured for fork length (FL), and scale samples were taken from a size range of each species to determine age; age 0 were young-of-the-year, and ages 1 and 2 had been in fresh water 1 and 2 winters, respectively. The life stage of age-1 and age-2 fish was categorized as either parr (typical freshwater coloration) or smolt (silvery appearance indicative of skin guanine; Rodgers et al. 1987). Catch was standardized by dividing the number caught by the hours fished.

Because of turbid water and fast current, fish probably could not avoid the net; however, small fish could pass through the 13-mm mesh. Size selectivity of the net was tested once by marking two size-groups of fish (18 coho <45 mm and 15 sockeye or coho >55 mm) and releasing them inside the net entrance. Test fish were marked by removing one tip of the caudal fin. All of the large size-group but only five (28%) of the small size-group were recovered in the live box, indicating that the net was inefficient at catching fish < 45 mm FL. Capture efficiency, however, varied during each set because fewer small fish could pass through the mesh as it was coated with debris.

River discharge, temperature, and turbidity were measured at the fyke net site. River discharge was determined from the cross-sectional area of the channel (measured with electronic distance and depth meters) and average velocity at 1-m depth (measured with a current meter). Discharge was measured at various river stages and regressed on river height determined by staff gauge; discharge for any given sampling period was determined from this regression. Temperature was determined every sampling period with a thermometer from 22 April to 8 July, and thereafter with a thermograph every 2 h. Turbidity in nephelometric units (NTU) was determined photometrically with a turbidimeter.

Conditions in the river changed seasonally during the study (Fig. 2). River discharge at the fyke net site increased from 100 m^3/s in late April to 1,900 m^3/s on 9 July (when the Tulsequah River flooded), then declined to 200 m^3/s in November. Changes in river temperature paralleled discharge, rising from 2°C in late April to 12°C in July and declining to nearly 0°C in November. Turbidity averaged about 200 NTU but varied directly with discharge, ranging from 18 NTU in low water in November to nearly 400 NTU during Tulsequah floods.

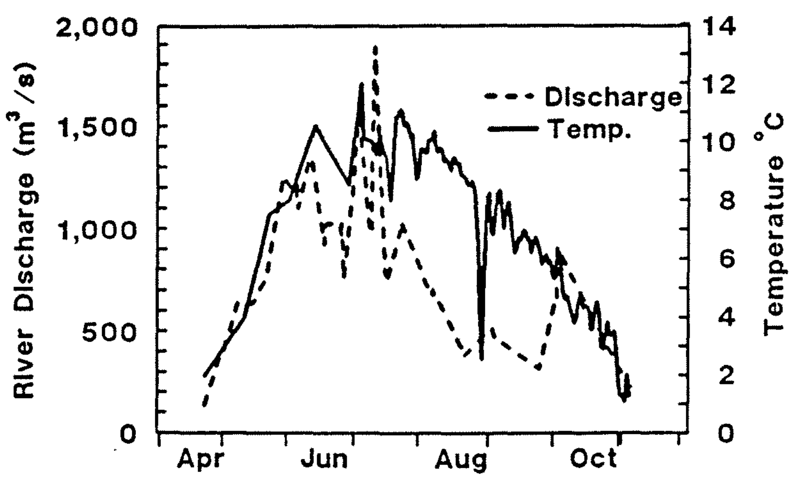

Fig. 2.--Physical characteristics of the Taku River, Alaska, late April to November, 1987.

Estuary Sampling

To monitor fish in the estuary, three study sites were established: Taku Point near the middle of the tide flats; Chum Cove in the lower end of the tide flats; and Smelt Cove in the outer basin (Fig. 1). Two adjacent beaches at each site were seined every week from 8 May to 26 June, and every 2 wk thereafter until 28 August; inclement weather curtailed sampling in September.

To catch fish in the estuary, we used a beach seine 37 m long and 2 m deep, with a central bag of 6-mm mesh and wings of 16-mm mesh. The seine was set from a skiff 40 m from shore and retrieved from shore with ropes. Catch was treated the same as from the fyke net. For logistical reasons, Taku Point was seined at high tide and the other sites at mid-tide.

The three estuary sites represented a salinity gradient. The Taku Point site had low salinity (<3 ppt); it was adjacent to river and tidal currents, and had shallow water (<3 m deep) and a sandy beach. Chum Cove had moderate salinity (5-26 ppt); it was sheltered from currents and had shallow water (<4 m deep) and a rocky beach. Smelt Cove had moderate salinity (5-25 ppt) reduced by a small stream; it was sheltered from current and had deep water (>8 m deep) and a rocky beach. For comparison, salinity of the surface 14 m of water at the mouth of Taku Inlet ranged from 16 to 28 ppt. Water temperature was similar at the three study sites and increased from 6°C in early May to 8-13°C in July and dropped to 5°C in late August. Turbidity decreased with distance from the river:

Secchi disk visibility was only 5-25 cm at Taku Point compared to 20-60 cm at Chum and Smelt Coves and 100-150 cm outside Taku Inlet.

RESULTS

Composition of the catch differed between the river and estuary, and catch in both areas changed seasonally (Fig. 3). In the river, catch was dominated by age-0 chum in May, age-0 coho and sockeye in June through September, and age-0 coho in November. In the estuary, catch was dominated by age-0 chum in May and June, and age-0 sockeye in July to September. The river catch of over 10,000 salmon was 49% coho, 35% sockeye, 10% chum, and 6% chinook; whereas the estuary catch of 2,600 salmon was 61% chum, 20% sockeye, 10% chinook, and 7% coho. Pink salmon made up 0.2% of the catch in the river and 2% in the estuary. Catch from the river and estuary probably differed because some fish (e.g., age-0 coho) moved downstream but remained in the lower river, whereas others (e.g., chum) migrated to sea.

Chum Salmon

Age-0 chum moved downstream mostly in May, and were common in the estuary from mid-May to late June (Fig. 4). Peak catch of downstream migrants was on 7 May, followed 3 wk later by a similar peak in the estuary. Modal FL of downstream migrants remained at 40 mm in May and June, as small chum continuously migrated to the estuary, and chum caught in the river averaged 6 mm smaller ($\underline{P} < 0.001$; $\underline{t}$ test) than in the estuary (Fig. 5).

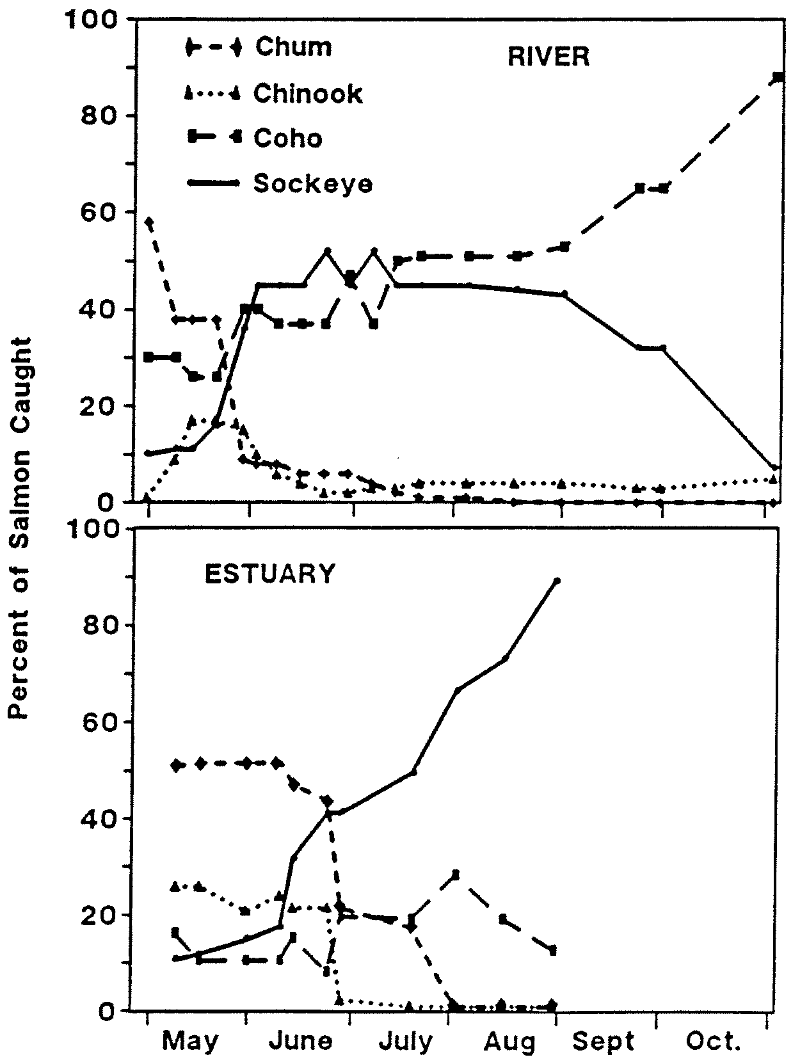

Fig. 3.--Species composition of juvenile salmon captured by fyke net in the Taku River, Alaska, 29 April - 4 November, and by beach seine in the river's estuary, 8 May - 28 August 1987.

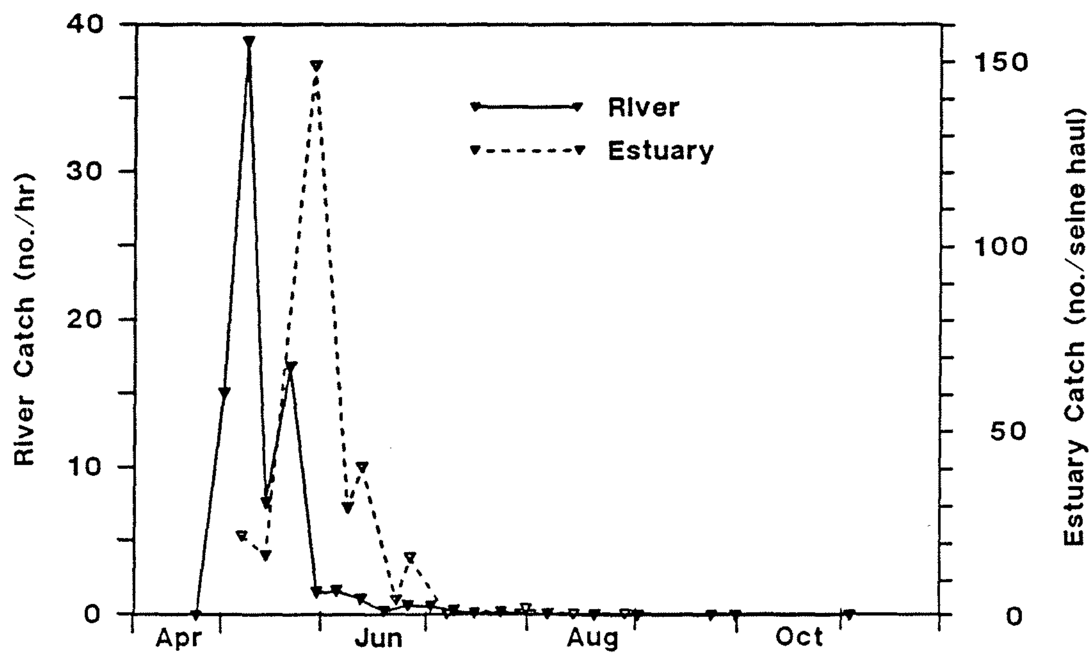

Fig. 4.--Catch of juvenile chum salmon by fyke net in the Taku River, Alaska, 22 April - 4 November, and by beach seine in the river's estuary, 8 May - 28 August 1987.

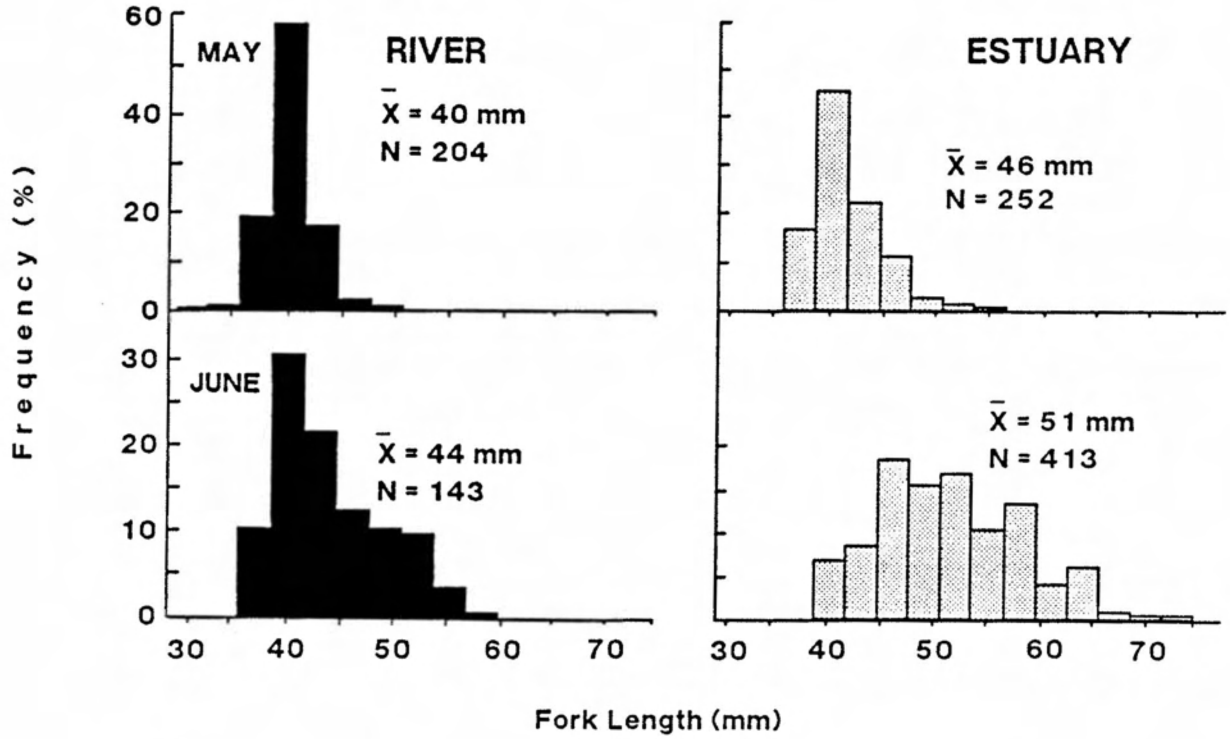

Fig. 5.--Length frequencies of juvenile chum salmon caught in the Taku River and estuary, Alaska, May and June 1987. Means ($\bar{X}$) and sample sizes (N) are shown for each month.

Chinook Salmon

Chinook smolts moved downstream and through the estuary in May and June (Fig. 6). Peak catch of smolts in the river was on 7 May, followed by a peak in the estuary 3 wk later. Smolts ranged from 54 to 120 mm FL (mean, 74 mm) and were 98% age 1 and 2% age 2 (Figs. 7, 8). Some age-0 chinook moved downstream in August to November, but probably remained in the lower river, as only two age-0 chinook were caught in the estuary. Mean FL of age-0 chinook caught in the river increased from 39 mm in May to 63 mm in November.

All age-2 and many of the larger age-1 chinook migrated early. Age-2 chinook were caught only in May, and chinook smolts in the estuary in May averaged 5 mm larger than migrants in the river ($P < 0.01$; t test; Figs. 7, 8). In June, however, smolts were the same mean FL (76-77 mm) in both the river and estuary because mean FL of downstream migrants increased during May and June while that of smolts in the estuary remained nearly constant.

Coho Salmon

Coho were the most abundant migrants in the river and exhibited a variety of migration patterns (Fig. 9). Smolts and parr (92% age 1, 8% age 2) moved downstream primarily in May and June, peaking around 7 May, and smolts were present in the estuary from early May to mid-August, peaking around 4 June. Age-0 coho also moved downstream, particularly in May and in August to November. In May, many age-0 coho (mean FL, 35 mm) moved downstream as river

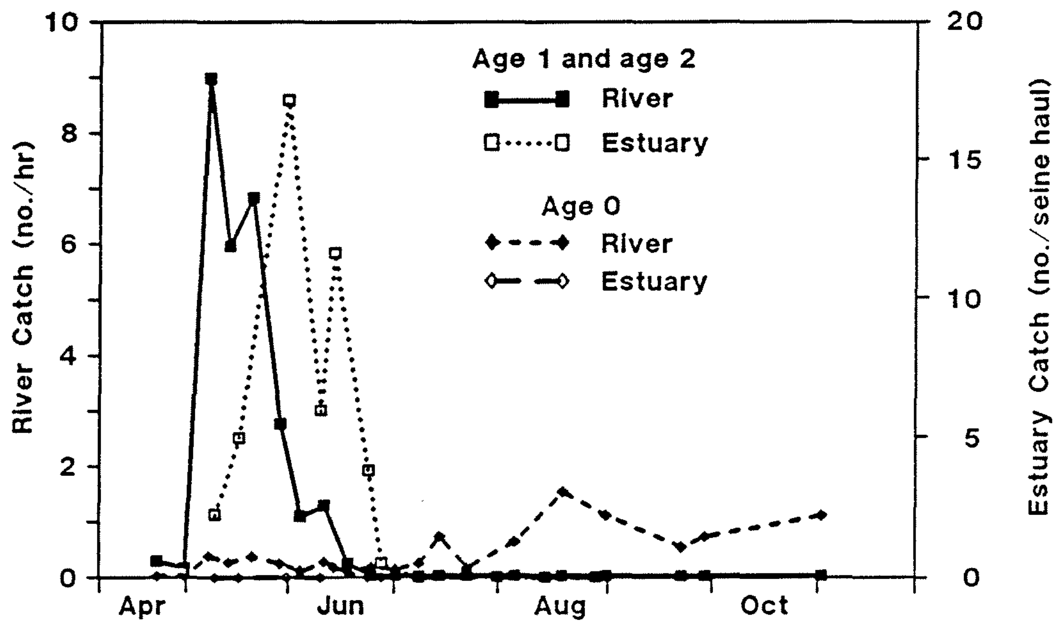

Fig. 6.--Catch of juvenile chinook salmon by age class from the Taku River, Alaska, 28 April - 4 November, and from the river's estuary, 8 May - 28 August 1987.

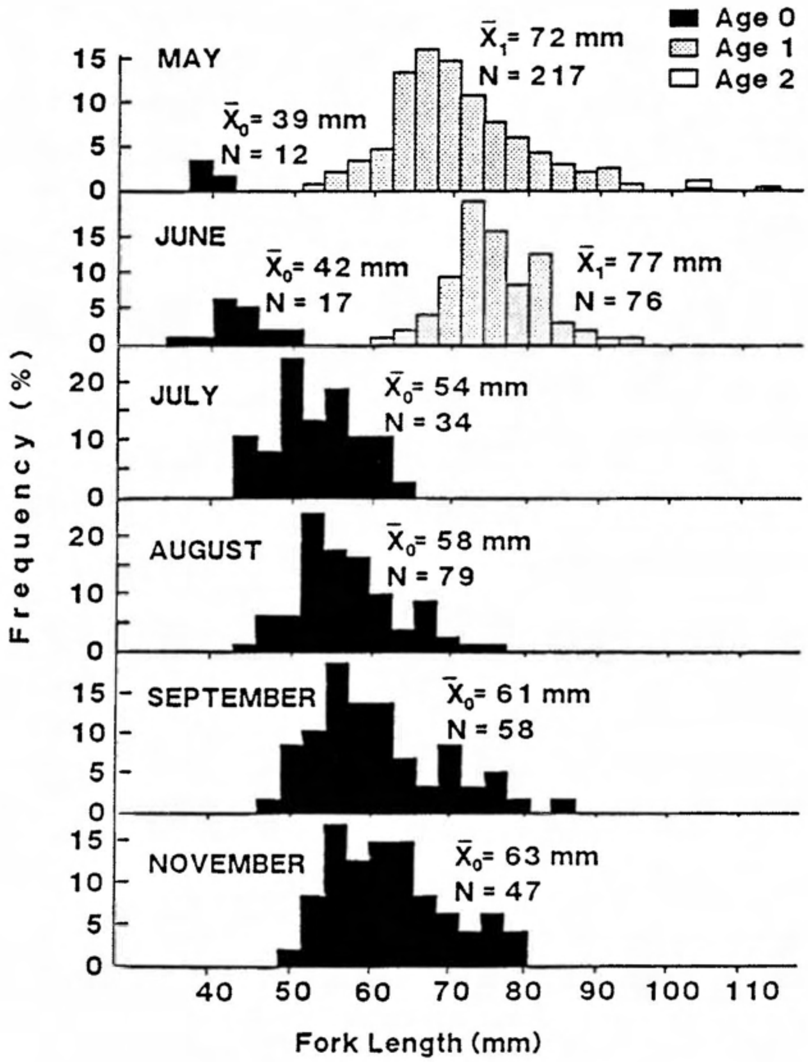

Fig. 7.--Length frequencies of juvenile chinook salmon by age class caught by fyke net in the Taku River, Alaska, May to November 1987. Means ($\bar{X}$) and sample sizes (N) are shown for each group.

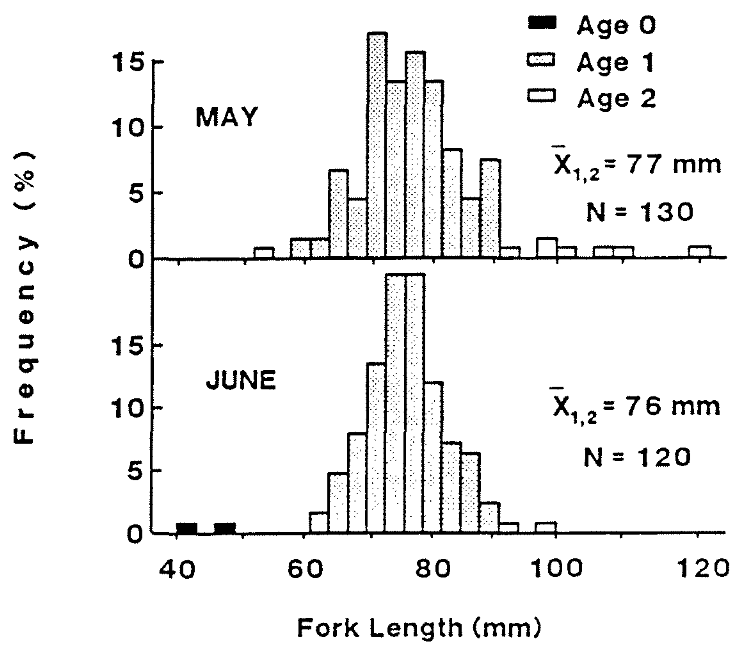

Fig. 8.--Length frequencies of juvenile chinook salmon by age class caught by beach seine in the Taku River estuary, Alaska, May and June, 1987. Means ($\bar{X}$) and sample sizes (N) are shown for combined age-1 and age-2 fish each month.

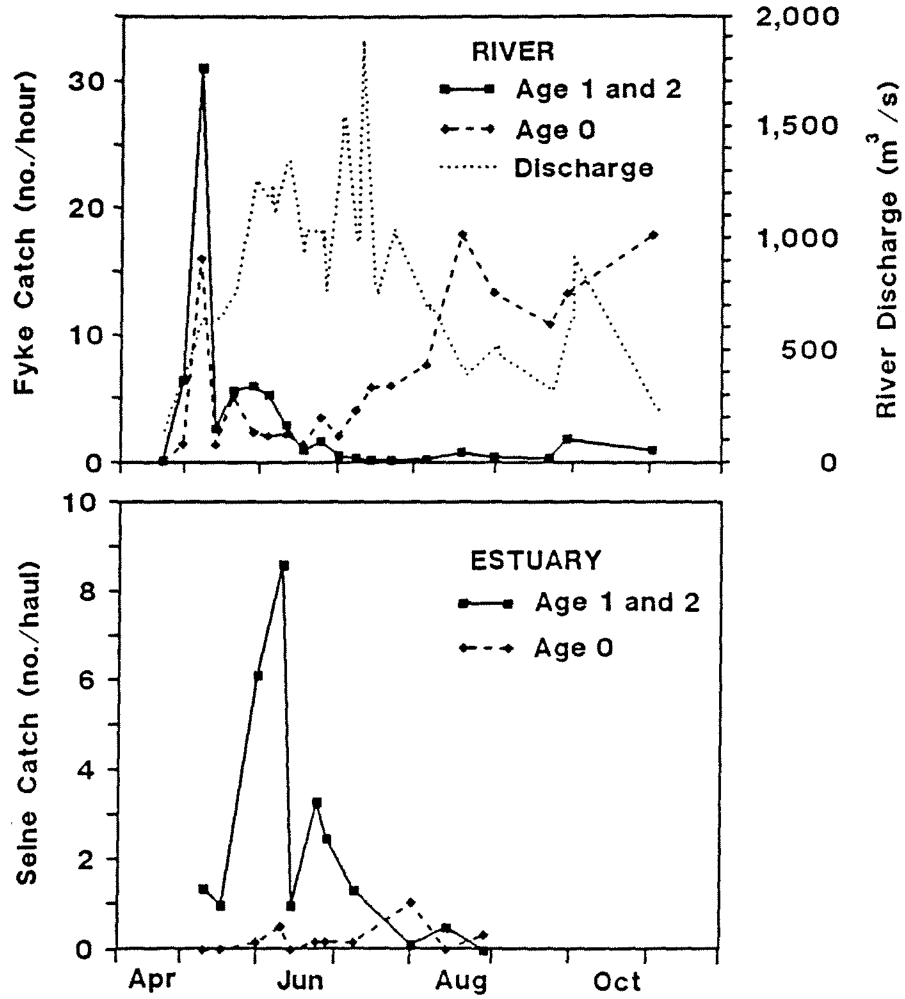

Fig. 9.--Catch of juvenile coho salmon by age class from the Taku River, Alaska, 28 April - 4 November, and from the river's estuary, 8 May - 28 August 1987. River discharge is plotted for comparison.

discharge increased; in August to November, larger age-0 coho (mean FL, 49-60 mm) moved downstream as the river receded (Fig. 10). Most age-0 coho, however, probably remained in the lower river, as only 12 were caught in the estuary.

Size, age composition, and stage of coho differed between the river and estuary. In May, 33% of coho smolts in the estuary were age 2, compared to only 7% of smolts and parr caught in the river, but in June, most age-2 coho had left, and they comprised less than 5% in both the river and estuary (Figs. 10, 11). In May, FL of coho smolts and parr in the river averaged 16 mm less than in the estuary ($\underline{P} < 0.001$; $\underline{t}$ test); however, in June, after most age-2 coho left, mean FL was the same (85 mm) in both areas. Parr made up 51% of the age-1 coho caught in the river in May and 37% in June, but no parr were caught in the estuary. Thus, the oldest and largest coho migrated early, while the smaller age-1 coho probably remained in the lower river in May, where they grew and transformed to smolts before going to the estuary.

Sockeye Salmon

Sockeye salmon also exhibited a variety of migration patterns (Fig. 12). Age-1 sockeye smolts moved downstream and through the estuary in May and June. Peak catch of smolts in the river was on 7 May, and peak catch in the estuary was 1 mo later. Age-0 sockeye moved downstream throughout the spring and summer, but were particularly abundant in July through September. Unlike age-0 coho and

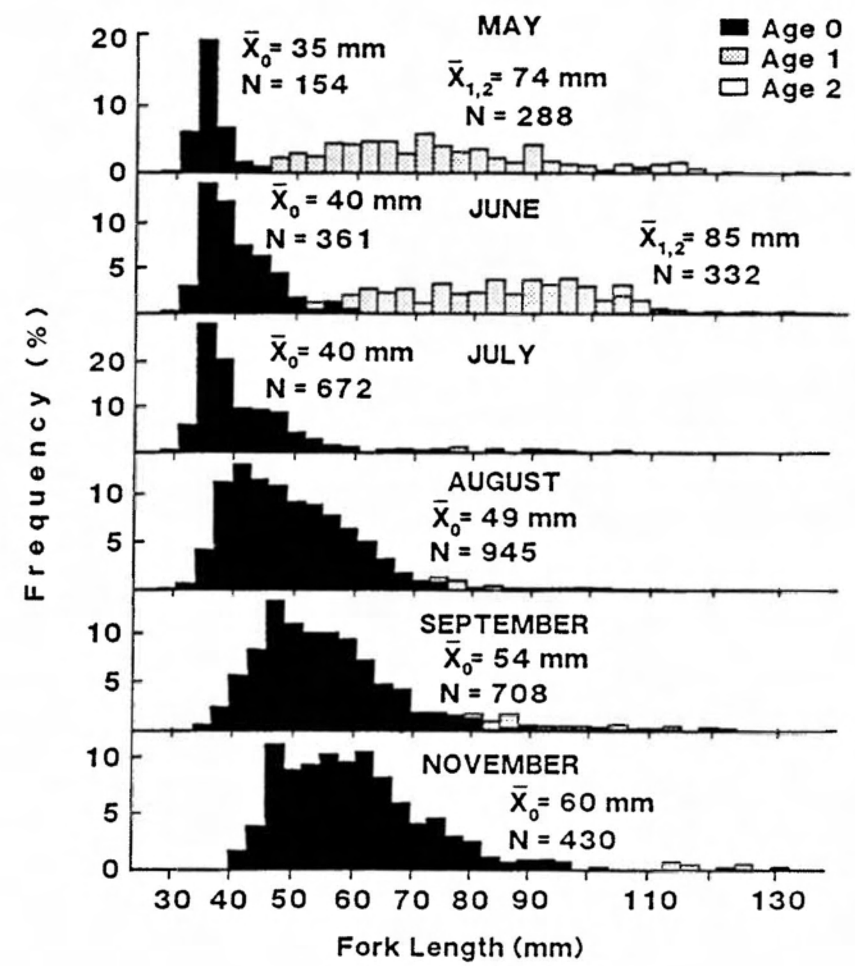

Fig. 10.--Length frequencies of juvenile coho salmon by age class caught by fyke net in the Taku River, Alaska, May to November 1987. Means ($\bar{X}$) and sample sizes (N) are shown for each age group.

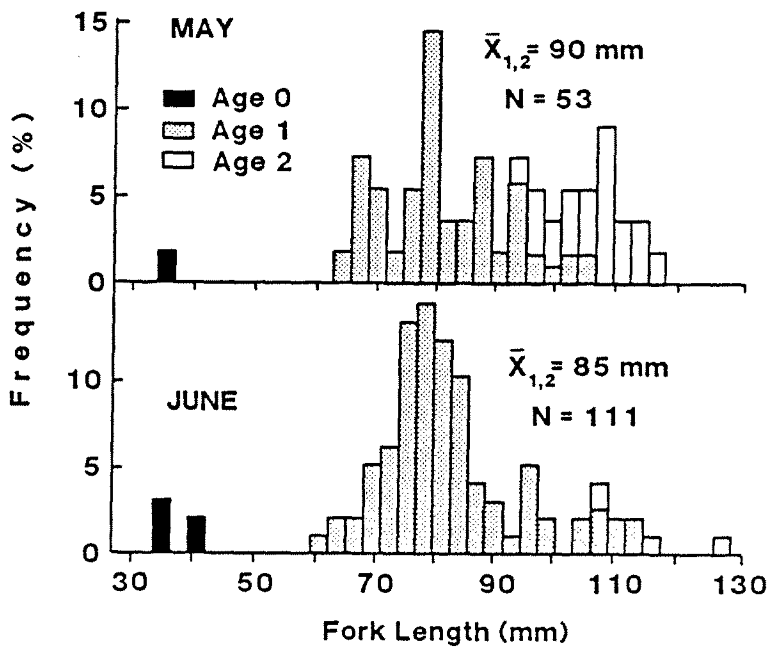

Fig. 11.--Length frequencies of juvenile coho salmon by age class caught by beach seine in the Taku River estuary, Alaska, May and June 1987. Means ($\bar{X}$) and sample sizes (N) are shown for combined age-1 and age-2 fish each month.

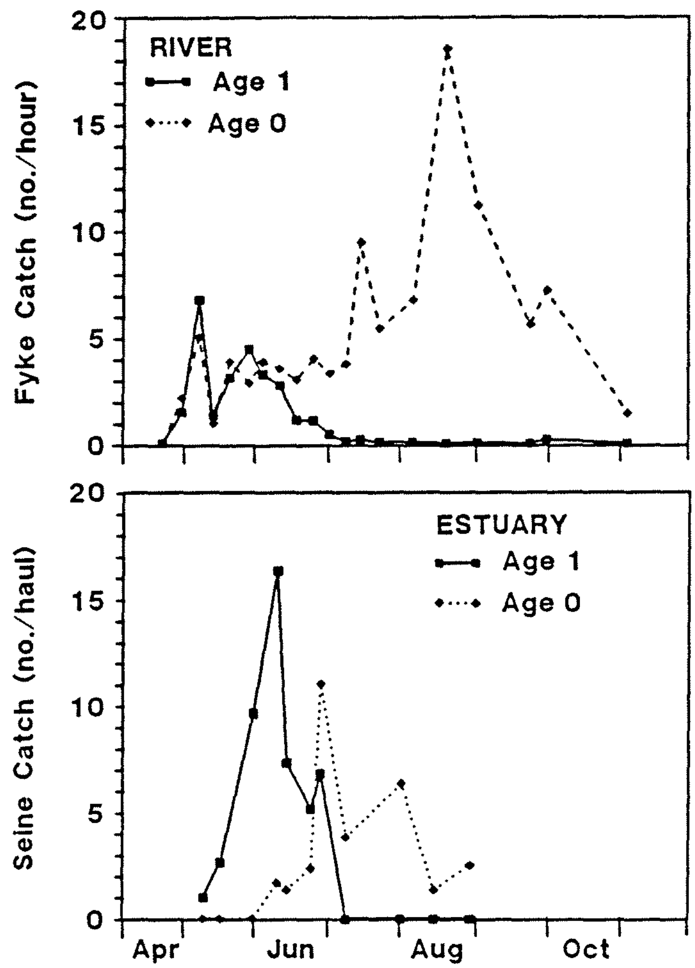

Fig. 12.--Catch of juvenile sockeye salmon by age class from the Taku River, Alaska, 28 April - 4 November, and from the river's estuary, 8 May - 28 August 1987.

chinook, many age-0 sockeye entered the estuary where they were the most abundant salmon in summer.

Sockeye smolts consisted of two size-groups, and most larger smolts migrated early. In May, FL frequencies of smolts displayed two modes: a primary at 58-63 mm and a secondary at 70-75 mm (Figs. 13, 14). The larger size-group was more abundant in the estuary, and smolts averaged 6 mm larger in the estuary than in the river (*t* test; $P < 0.001$). In June, after most of the larger size-group left, smolts were the same mean FL (65 mm) in both areas because mean FL decreased in the estuary while it increased in the river.

Age-0 sockeye also consisted of two size-groups that moved downstream at different times. The first group consisted of small, newly emerged fish (mean FL, 32 mm) that moved downstream in May and June but did not enter the estuary immediately. Even though catch of age-1 smolts and small age-0 fish were similar in the river in May and June, age-0 sockeye did not appear in the estuary until mid-June, a month after smolts (Fig. 12). Further, small age-0 fish were never common in the estuary, even though they moved downstream in large numbers in May and June (Figs. 13, 14). These small fish may have reared in the lower river and entered the estuary later.

The second group of age-0 sockeye to migrate consisted of larger fish (mean FL > 50 mm) that moved downstream in large numbers in July to October. These fish began to migrate suddenly in early July and were distinct in size from earlier migrants. In

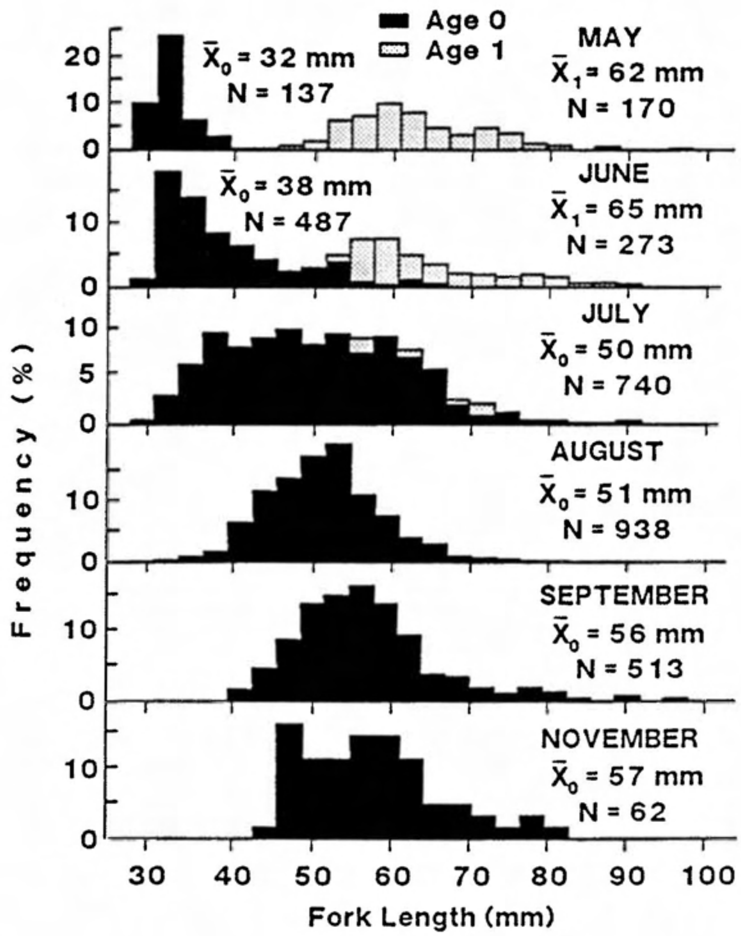

Fig. 13.--Length frequencies of juvenile sockeye salmon by age class caught by fyke net in the Taku River, Alaska, May to November 1987. Means ($\bar{X}$) and sample sizes (N) are shown for each age group.

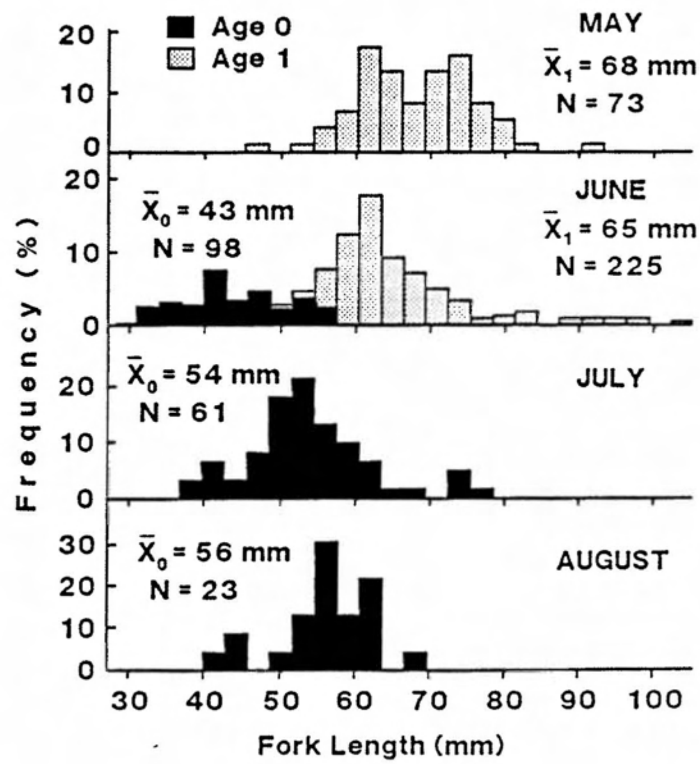

Fig. 14.--Length frequencies of juvenile sockeye salmon by age class caught by beach seine in the Taku River estuary, Alaska, May to September 1987. Means ($\bar{X}$) and sample sizes (N) are shown for each age group.

early July, catch of downstream migrants increased sharply, peaked in mid-August, and declined sharply through September (Fig. 12). In July, the FL frequency distribution broadened significantly ($\underline{P}$ < 0.01; $\underline{F}$ test; Fig. 13) as the larger size-group began to migrate downstream. Mean FL increased sharply in early July, and regressions of mean FL on sample dates before and after late June were significantly different ($\underline{P}$ < 0.01; $\underline{F}$ test), separated by a 10-mm gap (Fig. 15). In August-September, the frequency distribution was normal, with a mean FL of 53 mm (Fig. 13).

Presence of age-0 sockeye in the estuary coincided with the downstream migration of the larger size-group in the river. In late June, catch of age-0 sockeye in the estuary increased sharply, preceding by 1 wk the sudden downstream migration of the larger size-group in the river (Fig. 12). The slightly earlier increase in catch in the estuary than in the river may have been sockeye migrating from rearing areas in the lower river. Catch in the estuary, however, declined in August while the downstream migration peaked; two glacial floods in the estuary in August probably reduced the catch there. In July and August, the FL frequency distribution in the estuary was normal, with a mean of 55 mm, and was nearly the same as in the river (Figs. 13, 14). Sockeye less than 50 mm FL, however, were significantly ($\underline{P}$ < 0.001; Kolmogorov-Smirnov test) less common in the estuary than among downstream migrants in July (Fig. 16), indicating that the larger fish entered the estuary without delay while the smaller fish remained for a time in the lower river.

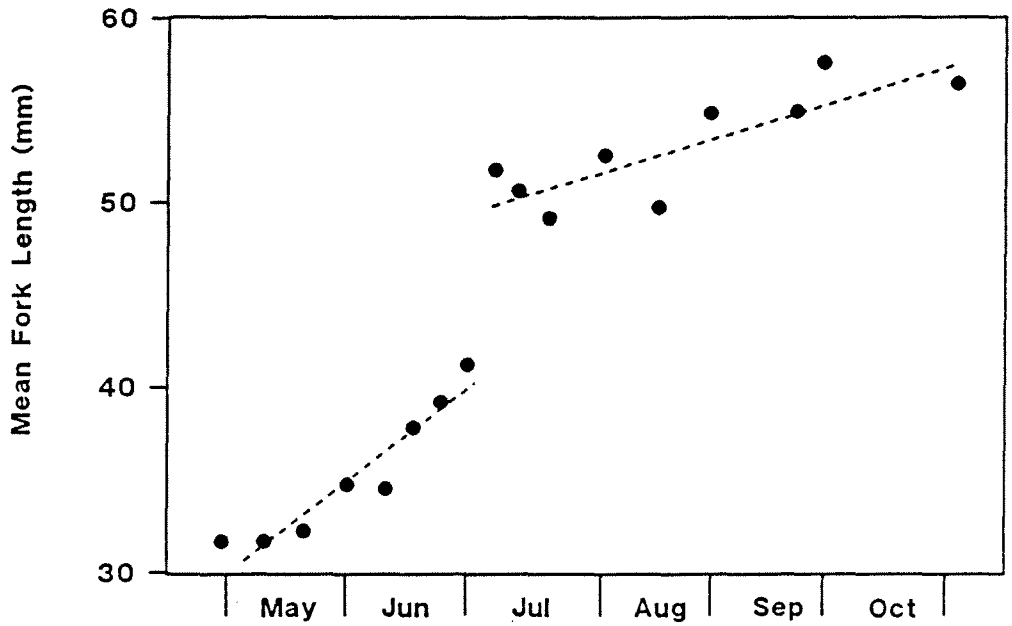

Fig. 15.--Mean fork length of age-0 sockeye salmon caught by fyke net in the Taku River, Alaska, 1987. Lines were fitted by regression. Total number of fish measured was 2,877.

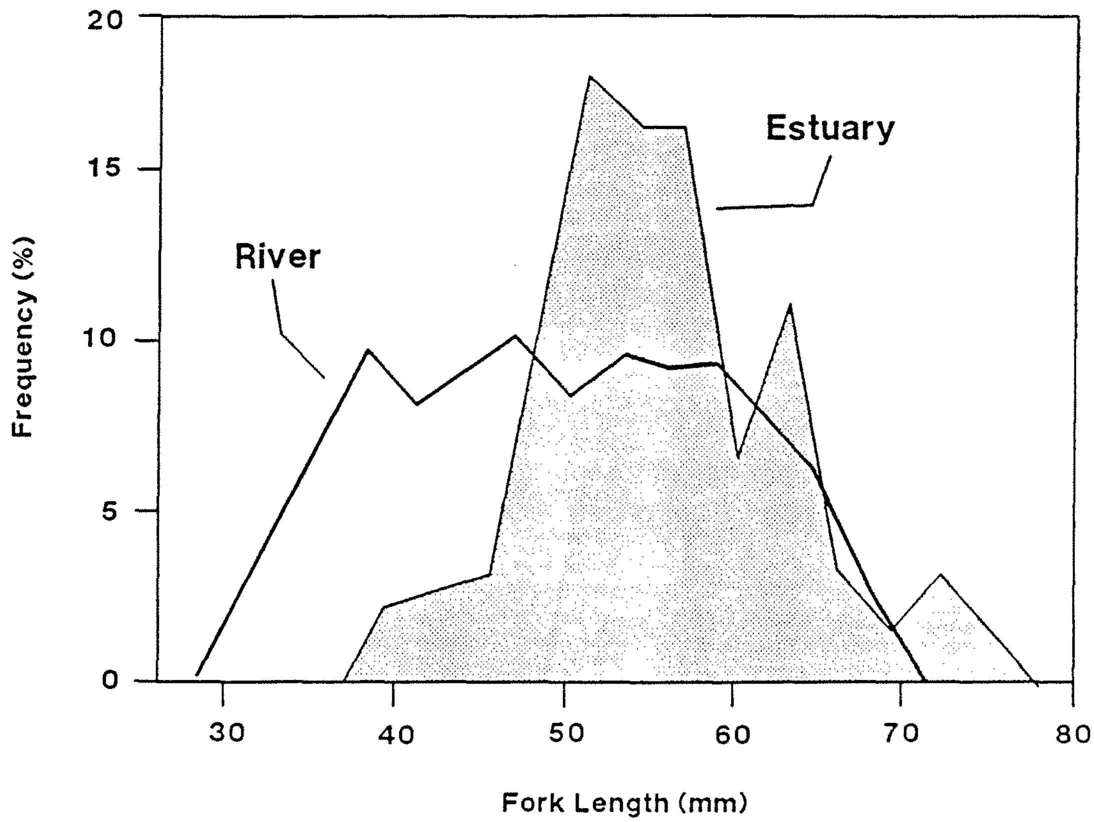

Fig. 16.--Length frequencies of age-0 sockeye salmon caught by fyke net in the Taku River, Alaska, and by beach seine in the river's estuary, July 1987. Number of fish measured was 740 in the river and 61 in the estuary.

DISCUSSION

Downstream migration of juvenile salmon in the Taku River involved several life stages of each species. Only some of the fish that moved downstream, however, actually entered the estuary and went to sea. In spring, as the river rose, age-1 and age-2 salmon smolts and age-0 chum migrated to sea, while newly emerged sockeye and coho moved downstream but remained in the lower river. Then in summer and fall as the river receded, larger age-0 coho and chinook moved downstream but remained in the river, while age-0 sockeye migrated to sea.

The spring migration of newly emerged fish is a typical event in many streams (Chapman 1962). As they begin feeding, young salmonids are vulnerable to being swept downstream (Ottaway and Clarke 1981), or they may be forced out by socially dominant fish (Mason and Chapman 1965). In the Taku River, many newly emerged fish probably were swept downstream involuntarily as the river rose sharply in May and June.

The summer migration of larger (50-60 mm) juvenile salmon in the Taku River differs from the typical pattern in other studies. Downstream movement usually occurs either in spring, when newly emerged fish move downstream and smolts migrate to sea, or fall, when fish move to winter habitat or are displaced by freshets; whereas summer is a time of little movement (Crone and Bond 1976). The summer migration in the Taku River may have been caused by shrinking habitat as river discharge dropped 80% between early July and November. Abundance of coho is directly related to pool volume

(Nickelson and Reisenbichler 1977; Murphy et al. 1986), and a decrease in pools in the river or its tributaries probably would cause coho to migrate.

The fate of age-0 downstream migrants depends on the species. The lower Taku River, along with its off-channel habitats on the valley floor, offers extensive rearing area for juvenile chinook, coho, and sockeye (Murphy et al. in prep.). Spawning habitat is limited in the lower river (Kissner 1984; Eiler et al. 1988); hence, much of the rearing habitat there probably is colonized by migrants from upriver. All adult coho and chinook returning to the Taku River show at least one freshwater annulus on their scales, whereas 15% of adult sockeye lack any freshwater annuli and went to sea as underyearlings (Kissner 1984; McPherson and McGregor 1986; Elliott and Kuntz 1988). Thus, migrant age-0 chinook and coho probably remained and reared in the lower river, whereas many age-0 sockeye migrated to sea.

The seaward migration of age-0 sockeye shows two patterns in recent studies: a spring migration of newly emerged fry that go and rear in an estuary (Heifetz et al., in press) and a summer migration of larger juveniles that had reared several months in the river (Wood et al. 1987). Because sockeye must attain a minimum FL of about 50 mm to survive in seawater (Heifetz et al., in press; Koski and Rice, unpublished data available from Auke Bay Laboratory, P.O. Box 210155, Auke Bay, AK 99821), they initially must rear in fresh or brackish water. For example, newly emerged sockeye in the Situk River, Alaska, rear in tidal sloughs in the salt marsh (Heifetz et al., in press). In contrast, age-0 sockeye in the Fraser River, B.C., move to the estuary in late June and July at a size of 50-70 mm (Birtwell et al. 1987). In our study, newly emerged sockeye moved downstream in spring but did not go to the estuary immediately; most age-0 sockeye probably went to sea in summer at a mean FL of 55 mm after rearing in the river for several months.

The lower Taku River appeared to be a staging area where seaward migrants delayed going to the estuary while they grew and transformed to smolts. For most species, peak downstream migration was 3 to 4 wk before peak numbers in the estuary. Thus, many fish took nearly a month to travel the 17 km from the fyke-net site to the estuary. Many age-0 sockeye migrated downstream in May but did not appear in the estuary until late June. Furthermore, disparities in size, stage, and age composition between downstream migrants and fish in the estuary indicated that the largest and oldest fish moved directly to the estuary while the smaller juveniles reared for a time in the lower river. One-quarter of the age-1 coho downstream migrants in May were smaller than the smallest coho caught in the estuary, and one-half had not yet transformed to smolts. Many of these small migrants probably grew and transformed to smolts in the lower river.

Such staging in the lower river, however, was limited to the early migration period. In June through August, fish in the estuary were the same size as downstream migrants, indicating that migrants quickly moved to and through the estuary without growing.

Yearling sockeye and chinook smolts typically spend little time in estuaries, but some coho smolts and age-0 chum, chinook, and sockeye may rear in an estuary for several months before dispersing to sea (Healey 1982). The Taku River estuary is highly turbid, which may limit prey production (Edmundson and Koenings 1986) and foraging success of salmon (Lloyd et al. 1987). Thus, seaward migrants may quickly pass through the estuary in search of food.

CONCLUSIONS

Downstream migrations in the Taku River lasted throughout the spring, summer, and fall. Smolts migrating seaward left the river primarily in May and June, though some coho left in July and August, and age-0 sockeye left from late June to October. Many age-1 and age-2 fish of all species appeared to delay going to the estuary in May while they grew and transformed to smolts in the lower river. Age-0 coho and chinook migrated downstream in large numbers in summer and fall but appeared to stay in the lower river and probably wintered there. Thus, the lower Taku River provides habitat for staging of seaward migrants in spring, as well as habitat for summer rearing and overwintering.

Important research questions remain to be answered. Large numbers of age-0 sockeye go to sea in summer, but their marine mortality is unknown. In addition, the origin of the age-0 coho and chinook migrants, the reason for their migration to the lower river, and their fate are unknown. If their migration is caused by habitat shrinkage due to receding water levels, then the river's carrying capacity may depend on water level. The importance of the lower river as wintering habitat also should be considered, as migrant salmon appear to rear in the lower river, but their winter mortality is unknown.

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