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DISTRIBUTION AND ABUNDANCE OF JUVENILE SALMON IN TWO MAIN CHANNEL HABITATS-OF THE TAKU RIVER, ALASKA AND BRITISH COLUMBIA

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ABSTRACT

Juvenile salmon (Oncorhvnchus spp.) abundance, species composition, and habitat use were studied in the lower (United States), middle (Canada), and upper (Canada) sections of the Taku River. In August 1987, 12 reaches in each of 2 habitat types (channel edges and sloughs) were sampled in each river section (total N = 72). Mean salmonid density (all species combined) differed less than l0% between any two river sections and was not significantly different between river sections in either habitat type. Chinook (O. tshawytscha) and sockeye salmon (0. nerka) were the most abundant fish species in all river sections and made up 87% of the catch. Nearly all (>98%) chinook and sockeye salmon were young-of-the-year. Chinook salmon density was similar in all river sections, but sockeye, salmon density decreased from the lower to the upper study section Water velocity increased while turbidity decreased between the lower and upper study sections.

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INTRODUCTION

The Taku River flows through both British Columbia, Canada, and Alaska,. United States, and provides spawning and freshwater rearing habitat for Pacific salmon (Oncorhynchus spp.) that sustain valuable fisheries. Management goals for Taku River fisheries pursued by both countries include optimum natural production and an equitable fishery yield for each country (Natural Resources Consultants 1986). Management of commercial fishing for Taku River salmon is complex because many salmon stocks occur in the river and the population dynamics of most stocks are unknown. Some Taku River salmon stocks are depleted from historical levels (Van Alen and Olsen 1986); optimum escapement levels for other salmon stocks are generally unknown. Information on juvenile salmon distribution and habitat use is needed to improve escapement goals for Taku River- salmon stocks and also to provide insights. into their restoration and enhancement.

Lower reaches of the Taku River (U.S.) provide summer rearing areas for many juvenile sockeye (0. nerka), chinook (0. tshawytscha), and coho (0. kisutch) salmon (Murphy et al. 1989). Juvenile salmon also occupy upriver (Canada) areas (Kissner 1984; Pat Milligan[1]), where their abundance and distribution is relatively unknown. This study was initiated to determine whether methods of habitat classification and. fish sampling used in the lower Taku River (Murphy et al. 1989) are appropriate for studying upriver areas. The study compares summer density, species composition, and habitat use of juvenile salmon in similar habitats in three morphologically different sections- of the Taku River..

STUDY AREA

The Taku River drains about 16,000 km^2 of the Cassiar and Coast Mountain Ranges of northern British Columbia and Southeast Alaska. The study area was the main stem of the Taku River, from its origin at the confluence of the Nakina and Inklin Rivers in British Columbia, to its mouth in Taku Inlet near Juneau, Alaska (Fig. 1). Over 90% of the watershed and nearly 70% of the 60-km long main, stem is in Canada.

The Taku River is typical of many large, salmon-producing rivers in Alaska and western Canada. It is glacier-fed and, consequently, is turbid, has rapid fluctuations in flow, and transports a large sediment load. From late spring

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[1]Pat Milligan, Fishery Biologist, Canada Dep. Fisheries and Oceans, 122 Industrial Rd., Whitehorse, Yukon Y1A 2T9. Pers. commun., May 1989.

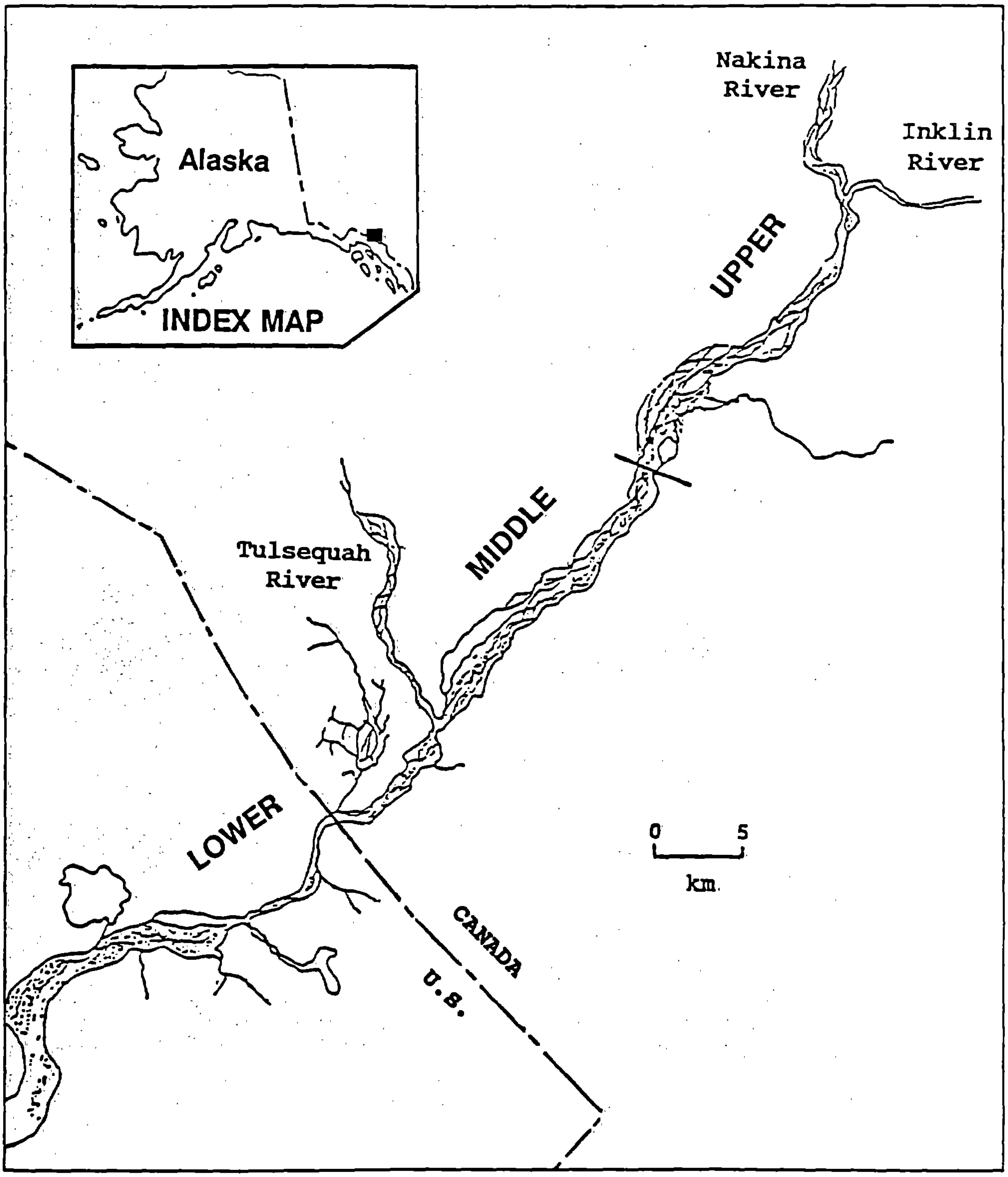

Figure 1.--Sections of the Taku River, British Columbia and Alaska, sampled in three river regions and two, habitat types for juvenile salmon abundance and habitat characteristics, August- 1987.

through summer, turbidity in the lower Taku River averages about 200 nephelometric units (NTU) and discharge usually exceeds 500 m^3/s. Summer flooding in the lower river, caused by the breaking of ice dams that impound parts of the Tulsequah River (Fig. 1), can increase turbidity to over 300 NTU and discharge to over 2,000 m^3/s (Clark et al. 1986). Turbidity and discharge decrease from fall through early spring. The wide floodplain (3 km in some areas), braided channels, and extensive tidal flats at the. river mouth result from the large sediment load transported by the river.

METHODS

In August 1987, juvenile salmon abundance, species. composition, and habitat were compared in three distinctly different sections (Fig. 1) of the Taku River's main stem: lower, middle, and upper river. Lower river (km O-16) gradient averaged less than O.l%, the main channel generally was greater than 100 m wide,. braids were few compared to other river sections,. and islands were predominately stable with dense vegetation.. Middle river (km 17-31) gradient usually was 0.1 to 0.2%, the main channel usually was less than 100 m wide, braids were numerous, and islands were predominately stable with dense. vegetation.. Upper river (km 37-55) gradient was usually greater than 0.2%, the main channel was usually less, than 100 m wide,. channels were profusely braided, and most islands were unstable with sparse vegetation. (Section km 32-36 was not sampled.)

Juvenile fish density and habitat characteristics were measured in 36 reaches of the main channel in each of two habitat types: channel edges--the margins. of main channels where velocity is less than 30 cm/s; and sloughs (secondary channels adjacent to the main channel) where water velocity is moderated by sediments blocking the head of the channel. We selected these habitat types for sampling for two reasons: 1) fish densities are generally less variable in channel edges and sloughs than in other. habitat types- in the main stem of the lower river (Heifetz et al. 1987); and 2) both of these habitat types were present, easily recognizable, and accessible in all river sections.

Fish were captured with seines (6-mm stretch mesh). Channel edges were sampled with a 3.7-m wide pole seine, pulled against the current, parallel to shore- for 20 m upstream (74-m^2 area). Sloughs were sampled with either a 23- or a 9.4-m long beach seine set perpendicular to shore and retrieved upstream in a 90° arc (areas of 415 and 70 m^2, respectively).

Captured fish were anesthetized with MS222, identified to. species, and measured for fork length (FL). Several scales between the dorsal fin and lateral line also were removed from each salmon and placed between acetate sheets for ageing. Ages were, determined for fish throughout the size range captured in each reach by counting winter growth checks on magnified (20-60 X) projections of the scales. Fish without winter growth checks on their scales were designated age 0, and fish with a winter check on the scales were designated age 1.

The number, of each species of fish in- each reach was- estimated by the removal method (Zippin 1958):

$$N = \frac{C}{1-(1-q)^n} \qquad (1)$$

where N = estimated-number of fish, C = total catch, n = number of hauls and q = probability of capture estimated by successive approximation (Moran 1951). A minimum of three seine hauls were made. in each reach, and. fish from each haul were. held in separate containers. If the catch on the third haul was not significantly reduced from that of the second haul, additional hauls were made until catch was' reduced from the previous. haul. Immigration and emigration during sampling were assumed to be negligible. The density of each fish. species was. determined for each reach by dividing the estimated number of fish. by the area sampled.

Habitat characteristics were measured- or estimated in each reach. Water depth (cm), average water- column velocity (cm/s), and temperature (°C) were measured along three. transects that were aligned perpendicular to the current at the beginning,- middle, and end of the seining area. At three points (one-quarter, one-half, and three-quarters of seine width) along each. transect, water depth. and velocity were measured with a stadia rod and an electronic flowmeter. Temperature in both the water column and approximately 15 cm into the substrate at the middle of each transect was measured with an electronic thermometer with a l-m thermistor probe. Water turbidity was measured in each reach with a nephelometer. Measurements of water velocity and turbidity also were taken, in at least 20 randomly- selected locations in main channels- (1.5 m from the water's edge) in each study section. Locations- were selected by motoring downstream for a random number of seconds (between 1 and 200) and alternating between banks of the river. Substrate composition was visually estimated and expressed by percentage of three particle-size classes: fine (<2 mm in diameter); gravel (2. mm-10 cm); and coarse, (>10 cm).

Densities of chinook, sockeye, and total salmonids in each habitat type were compared between study sections with a Kruskall-Wallis one-way analysis of variance by ranks. Central tendencies of fish densities within sections are reported as medians (values in the frequency distribution arrays with equal numbers of values on either side of them) rather than means because many reaches had fish densities approaching zero and. frequency distributions were negatively skewed. Differences in habitat characteristics between study sections were determined for each habitat type by multiple classification analysis of variance (ANOVA), with habitat type and river section as factors. Scheffe's test was used to determine differences between individual. study sections when. significant F values were indicated by ANOVA. The Chi-square method was used to test associations between fish species, habitat type, and study section.

RESULTS

Species: Composition and Abundance

Salmonid species. caught were chinook, sockeye, coho, chum (O. keta), and pink salmon (0. gorbuscha), whitefish (Prosopium sp.), Dolly Varden (Salvelinus malma), and steelhead trout (0. mykiss).. Mean salmonid density (all species combined) differed less than 10% between any two river sections and was not significantly different ($P > 0.3$; Kruskall-Wallis, test) between river sections in either habitat type. However; salmonid density varied among reaches within a river section (Fig. 2), and fish were not randomly distributed ($P < 0.01$; Chi-square test) among reaches in any river section. Salmonids were absent from only 1 of the 72 reaches sampled, but fish density within sections ranged widely from O-l to 117-212 fish/100 m^2.

Chinook and sockeye salmon made up 87% of the catch, and no other species made up more than 6% of the catch. The median density of chinook salmon was greater,-than that of sockeye in all sampling areas except the middle section of the. side sloughs (Fig. 2). Chinook salmon were caught in. 83% of the reaches, but most (64%) were associated with channel edges ($P < 0.03$; Chi-square test). Sockeye. salmon were caught in 60% of the reaches but most (70%) were associated with sloughs ($P < 0.05$).

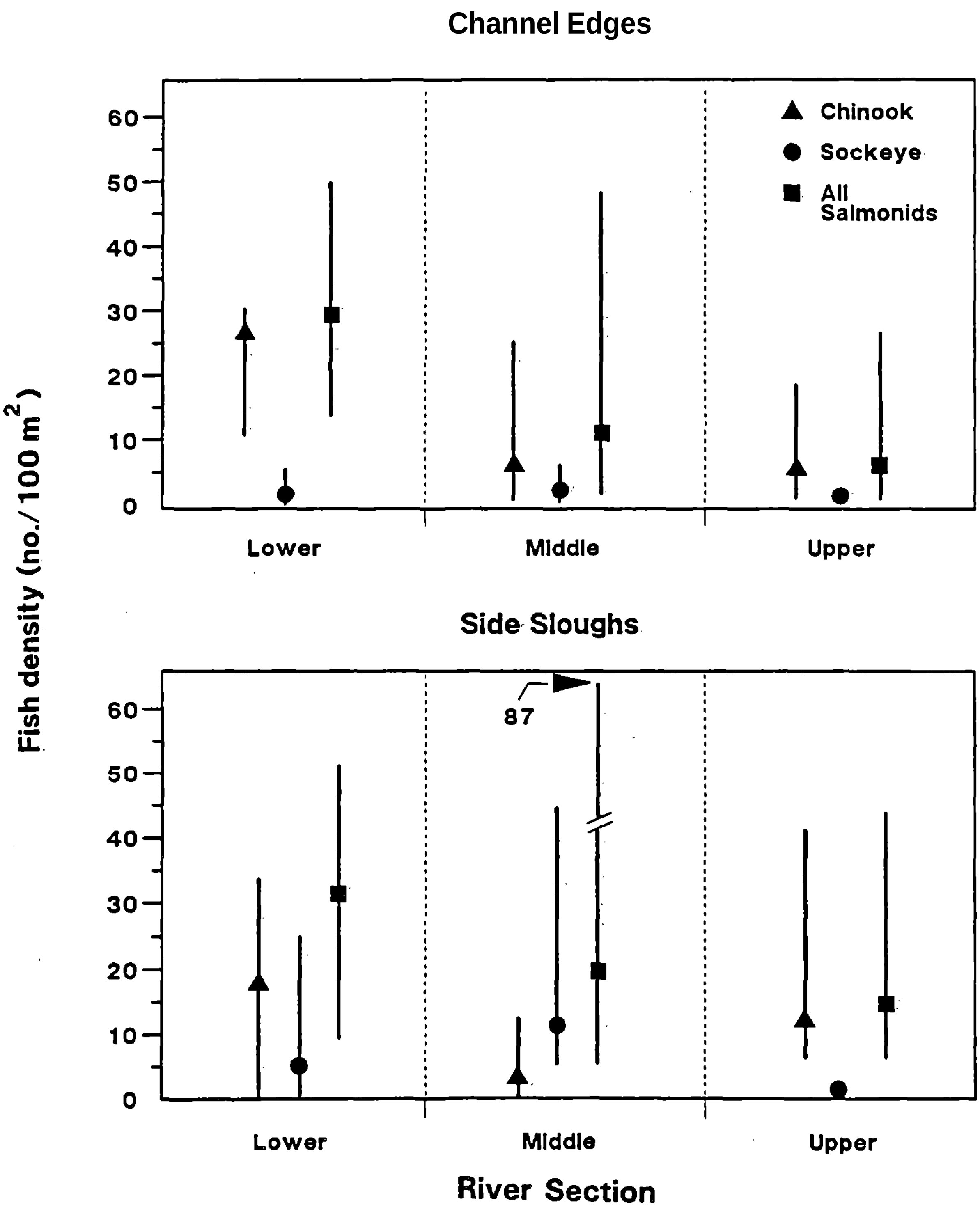

Figure 2.--Fish density by habitat type in three sections of the Taku River, Alaska and British Columbia, August 1987. Symbols denote median densities within the ranges shown by bars.

Sockeye salmon density in sloughs was significantly different ($P < 0.003$; Kruskall-Wallis test) between river sections, with medians ranging from 5 and 12 fish/100 m^2 in the, lower and middle sections, respectively, to 0 fish/100 m^2 in the upper section. Median chinook salmon density in channel edges ranged from 27 fish/100 m^2 in the lower section to 7 and 8 fish/100 m^2 in the middle and upper sections.

There was no significant difference ($P > 0.64$; F test) in length or age composition of chinook or sockeye salmon between river sections or habitat types. Chinook salmon averaged 56 mm FL and sockeye salmon averaged 49 mm FL. Nearly all (98%) chinook and sockeye salmon were age 0; the remainder were age 1.

Fish Habitat

All: habitat characteristics, except percent of gravel in the substrate differed significantly ($P < 0.05$; t test) between habitat types. Within a habitat type, some characteristics were significantly different between river sections (Table l), but most showed significant. interactions between habitat type and river section. Abundance of coarse sediment, water depth, and intragravel temperature were all significantly greater ($P < 0.05$; Scheffe's test) in the upper section than in the middle or lower, sections.. Fine sediment was significantly ($P < 0.05$) more abundant in the lower section than in the middle or upper sections. Average water velocity was significantly (P c 0.05) greater in the upper section than in the lower. section, and turbidity increased significantly ($P < 0.05$) in each progressive downstream section..

Random samples of water, velocity from main channels of each river section showed that velocity was significantly different ($P < 0.005$; F test) between sections. Mean velocities were 45.5 cm/s in the upper section, 30.9 cm/s in the middle section, and 21.1 cm/s in the lower section (Table 2). Water, velocities at randomly selected locations in the middle and lower sections of the river were significantly slower ($P < 0.005$ and $P < 0.01$, respectively; Scheffe's test) than water velocities in the upper section. Many locations had water velocities above the threshold level usually inhabited by rearing salmon (30 cm/s; Reiser and Bjornn 1979). Only 20% of the randomly selected locations in the upper section had velocities less than 30 cm/s, but availability of habitable water velocity increased downstream: water velocity at randomly selected locations in the middle, and lower sections was less than 30 cm/s in 32 and 56% of the cases, respectively.

Table 1.--Mean values (and 95% CI) for physical characteristics of two habitat types (channel edge, slough) in three sections (lower, middle, and upper regions) of the Taku River, Alaska and British Columbia,. August 1987. Within-habitat values that were significantly different at P < 0.05 between river sections are underlined.

Physical Characteristic	Channel edge			Slough		
	Lower	Middle	Upper	Lower	Middle	Upper
Turbidity (NTU)	218 (211-226)	144 (127-161)	104 (101-108)	110 (68-152)	99 (69-129)	44 (24-88)
Water velocity (cm/s)	16.6 (10-23)	23.7 (19-29)	41.7 (31-52)	0.9 (0-2)	2.2 (1-4)	6.4 (1-12)
Gravel (%)	70.8 (45-96)	80.8 (60-100)	96.7 (92-100)	3.3 (0-10)	6.3 (2-10)	16.7 (0-34)
Fine sediment (%)	29.2 (0-55)	10.8 (0-17)	3.3 (0-8)	96.7 (90-100)	93.7 (90-98)	83.3 (66-100)
Water depth (cm)	34.3 (27-41)	23.3 (21-26)	32.3 (27-38)	37.9 (29-47)	38.8 (25-52)	62.8 (47-78)
Water temp. (°C)	10.3 (10-11)	8.9 (8-10)	10.0 (9-11)	11.2 (10-12)	10.7 (8-13)	11.2 (10-13)
Substrate temp. (°C)	8.8 (8-10)	7.8 (6-9)	10.2 (9-11)	8.3 (7-9)	7.1 (6-8)	8.5 (7-10)

Table 2.--Water velocity at randomly selected locations in three main stem sections of the Taku River with the percentages of those locations within preferred and threshold ranges of juvenile salmonids, British Columbia and Alaska, August 1987.

		Percent of Locations		
		Preferred Range[a]:		
River section	Mean Velocity (cm/s)	Chinook (2-28 cm/s)	Sockeye (0-20 cm/s)	Threshold[b] (<30 cm/s)
Upper (N=23)	**45.5**	**20**	**10**	**20**
Middle (N=20)	**30.9**	**32**	**23**	**32**
Lower (N=25)	**21.1**	**48**	**36**	**56**
Overall Mean (N=68)		**34**	**21**	**37**

[a]Bovee (1978).

[b]Reiser and Bjornn (1979).

DISCUSSION

Salmonid Abundance and Species Composition

Salmonid abundance in the two habitats we sampled remained the same throughout the Taku River main stem. Species composition, however, changed with habitat and river section. The abundance and species composition of juvenile salmon sampled in the Taku River were generally similar to those from main channels of other Alaskan glacial rivers (Lake 1984); chinook and sockeye salmon were most abundant and other species were scarce. Other salmonids known to be abundant in the drainage (Meehan and Siniff 1962; Murphy et al. 1988b) were scarce in our samples. for at least two reasons: 1) most pink and chum salmon had migrated to sea before sampling began in August (Murphy et al. 1988b); and 2) some species avoid the habitat in the main channels of the Taku River. Coho salmon, for example, are abundant in side-channel habitats in the lower section of the Taku River (Murphy et al. 1989; Thedinga et al. 1988), but probably avoid the turbid (>70 NTUs) main-stem areas of the Taku River, as they do in some Idaho streams (Bisson and Bilby 1982).

Mean densities of chinook and sockeye salmon in the lower section of the Taku River (about 13 and 17 fish/100 m^2, respectively) were similar to previous estimates of rearing density for these species in the same area (about 16 and 19 fish/100 m^2, respectively; Murphy et al. 1988a). A similar density of chinook (about 12 fish/100 m^2), but a lower density of sockeye salmon (about 1 fish/100 m^2), have been reported in the lower Stikine River, Alaska (Edgington and Lynch 1986). Mean densities of chinook salmon in the middle and upper Taku River sections (23.2 and 32.3 fish/100 m^2, respectively) were greater than in other glacial rivers, but less than in its clearwater tributary, the Nahlin River (50 to 370 fish/100 m^2; Kissner 1976), or streams in Idaho (Hillman et al. 1987). Taku River sockeye salmon densities in all sampling categories were low when compared to the range of densities. reported for central British Columbia lakes (between 2 and 113 fish/100 m^2; Johnson 1956).

Fish Habitat

Channel edges and sloughs make up about 4% of the total area and about 15% of the habitable area in the lower main stem of the Taku River (Murphy et al. 1988a). These percentages probably decrease in the middle and upper sections of the river. For example, the amount of channel edge habitat per unit of stream length declines in successive upstream sections because the habitable margin along the channels becomes narrower as average water velocity increases. We also encountered fewer sloughs as we moved upstream and concluded that sloughs are probably less common in successive upstream sections.

Mean values for fish habitat characteristics in reaches we sampled were usually within ranges suitable for salmonid rearing. Most stream-dwelling salmonids prefer areas with water velocities less than 30 cm/s (Reiser and Bjornn 1979), water depths less than 1.2 m, temperatures between 6 and 24°C, and substrates ranging from silt to cobbles (Bovee 1978). More than any other habitat variable. sampled, water velocity affects habitat use by both chinook and sockeye salmon in glacial rivers (Murphy et al. 1989; Lake 1984). Chinook and sockeye juveniles do not use habitat in the lower Taku River where water velocity exceeds 30 cm/s (Murphy et al. 1989), and are most abundant where water- velocity is less: between 2 and 28 cm/s. for chinook (Murphy et al. 1988a) and between 0 and 20 cm/s for sockeye salmon (Heifetz et al. 1987).

Water velocity in the reaches we sampled was generally less than 30 cm/s; however, fewer than 30%. of randomly sampled, sites in the upper and middle sections. and just over 50%. of the sites in the lower section had habitable water. velocities (<30 cm/s;. Table 2). Even fewer sites had water velocities within the ranges preferred by either chinook or sockeye salmon. If our random measurements of water velocity accurately represent the amount of salmon rearing habitat available in summer. in the Taku River main stem, optimal rearing habitat is least available in the upper river and most available in the lower river.

Fish Distribution

This study indicates that, in summer, large numbers of juvenile chinook salmon reside in main channels of the Taku. River and their density is related to habitat type. When data: from both habitat types (channel edges and sloughs) were. combined, the highest mean densities of chinook salmon (28 fish/l00 m^2) were in the- upper study section, where overall mean water velocity and depth (16.4 cm/s and 46.2 cm, respectively) approached optimum levels for juvenile chinook salmon (about 18 cm/s and >43 cm, respectively; Bovee 1978). As in other studies of glacial rivers (Lake 1984; Murphy et. al.. 1988a), chinook juveniles in the Taku River used certain habitats more than others; chinook density was higher in channel edges than in sloughs.

Our observations also suggest that adequate winter habitat for juvenile chinook salmon is available in main channels of the Taku River. In winter, juvenile chinook salmon in some Alaskan rivers can be found in low-velocity deep water, and often use large woody debris for protective cover (Siedelman and Kissner 1988). In all of the study sections, we observed numerous debris jams in main. channels that may provide winter habitat. Scales from returning adults show that nearly all chinook juveniles in the Taku River spend one winter in fresh water before going to sea (Kissner and Hubartt 1986). Thus, the main channels of the Taku River are probably important rearing areas for these fish during their freshwater life history.

This study also indicates that many juvenile sockeye salmon in the Taku River migrate from natal areas in the upper main stem and move downstream to the lower river by late summer. Other studies show a similar April through October downstream migration by juvenile sockeye, coho, and chinook salmon into the lower sections of the river (Meehan and Siniff 1962; Murphy et al. 1988b). The origin of downstream migrants that we caught in the lower Taku River is generally unknown, but we assume that most juvenile salmon came from upstream spawning areas. There are two reasons for this assumption: 1) relatively little spawning by chinook (Kissner 1976) or sockeye salmon (Eiler, et al. 1988) occurs in the Taku River below our upper study section; and 2) declining river flows in late summer probably force the predominant side-channel species (sockeye. and coho salmon; Murphy et al. 1989) into main channels and thus, into downstream migration. This migration probably accounts for the decrease in the density of sockeye juveniles between the lower and upper study sections.

Murphy et al.. (1989) found that juvenile sockeye salmon in side channels in the lower Taku River use different habitat than fish in main channels, and speculate that most sockeye salmon in main channels were migrating downstream, Our study results, combined with those of previous downstream migration studies (Meehan and Siniff 1962; Murphy et al. 1988b) and what is known about life history patterns of Taku River sockeye salmon, support Murphy's, speculation.

Nearly 50% of the sockeye salmon that spawn in the Taku River main stem go to sea before their first winter, and nearly all sockeye salmon in the Taku River that spawn near lakes overwinter as juveniles (Eiler et al. 1988). If, as this study suggests, most downstream migrant sockeye salmon are progeny of main-stem spawners, they could follow either of the two life history patterns common for the offspring of adults, that return to spawn in the main stem (McPherson 1987;

Lorenz and Eiler 1989): 1) overwintering in the river and migrating to sea in the spring; or 2) migrating to sea before winter.

CONCLUSIONS

In late summer, the density of rearing salmon in the habitats that we sampled was similar in all sections of the Taku River main stem, but species composition and habitat characteristics differed between sections. Main channels of the Taku River were accessible to all salmon species that occur in the river; however, habitat characteristics probably regulate species composition and total numbers of salmon that rear in the main stem. Juvenile chinook and sockeye salmon were the most abundant fish in main channels and had densities comparable to those in similar, habitat in other glacial rivers, but lower than those, in nonglacial systems. This study indicates that main channels provide good summer rearing habitat for chinook salmon, but are less suitable for sockeye salmon, and are virtually unused by coho salmon. In summer, most chinook salmon in the Taku River main stem are probably resident, whereas many sockeye and most coho salmon are transient. Thus, main channel rearing areas are important for chinook, but only represent a small fraction of the summer rearing habitat of sockeye and coho salmon..

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