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ABSTRACT

Damming of Russell Fiord caused by the advance of the Hubbard Glacier will flood Old Situk River and the lower 20 km of the Situk River near Yakutat, Alaska, and may adversely affect juvenile salmonid rearing habitat. To obtain baseline data before the flooding, in 1989 , a study enumerated juvenile salmonids that migrated from Old Situk River . Juvenile salmonids were captured at a weir on Old Situk River-from 14 April to 2 July to evaluate smolt yield and winter habits, Coho salmon smolts (Oncorhynchus kisutch) were fin clipped and released 200 m upstream of the weir, and the percentage of recaptured fish (42%) was used to estimate total number of smolts. A total of 26,200 coho, 7,000 sockeye (O. nerka), 5 chinook salmon (O. tshawytscha), and 500 steelhead (0. mykiss) smolts were estimated to have migrated from Old Situk River. An estimated 93,000 coho parr (age 1) emigrated from Old Situk River and probably reared in the main-stem Situk River until smoltification. An estimated yield of 45 salmonids/100 m^2 ($\geq$ age 1) indicates that Old Situk River is an

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INTRODUCTION

Scientists predict that the Hubbard Glacier near Yakutat, Alaska, will advance, block off Russell Fiord, and form Russell Lake within the next several years (Mayo 1988). The lake is predicted to overflow into the Situk River drainage and flood Old Situk River (Mayo 1988)(Figs. 1, 2). Overflow from Russell Lake is predicted to drastically alter the physical characteristics of Old Situk River and the lower 20 km of the Situk River as peak flows increase by a factor of 10, water becomes glacial, and water temperature decreases (Mayo 1988; Paul 1988), resulting in changes to salmonid rearing and spawning habitat.

Five species of Pacific salmon (Oncorhynchus spp.), steelhead (O. mykiss), cutthroat trout (O. clarki), and Dolly Varden (Salvelinus malma) are indigenous to the Situk River. Approximately 2,000 coho (O. kisutch), 1,000 sockeye (O. nerka), and 5,000 pink salmon (O. gorbuscha) spawn in Old Situk River. Smaller numbers of chum (O. keta) and chinook salmon (O. tshawytscha), steelhead, and Dolly Varden also spawn in Old Situk River. Old Situk River is an important summer rearing area for juvenile salmonids (Thedinga[1]), but little is known about wintering populations.

Because flooding will affect valuable commercial, sport, and subsistence fisheries, it is important to determine the potential changes in salmonid rearing and spawning habitat. The objectives of our study were to enumerate juvenile salmonids emigrating from Old Situk River, and to evaluate the importance of Old Situk River as a critical wintering habitat for all salmonids.

STUDY AREA

The Situk River, located approximately 18 km from Yakutat, Alaska, flows through a glacial floodplain called the Yakutat Forelands (Figs. 1, 2). The Situk River (from Situk Lake to salt water) is 29 km long, averages 25 m in width, has a mean summer discharge of 5.6 m^3/s, and drains an area of about 20,000 ha (U.S. Forest Service 1985). Old Situk River, a major tributary to the Situk River, is approximately 20 km long, averages 12 m in width, has a mean summer discharge of 1.5 m^3/s and is spring fed. Because Old

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[1]John F. Thedinga. 1990. Auke Bay Laboratory, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA, 11305 Glacier Highway, Juneau, AK 99801. Unpubl. data.

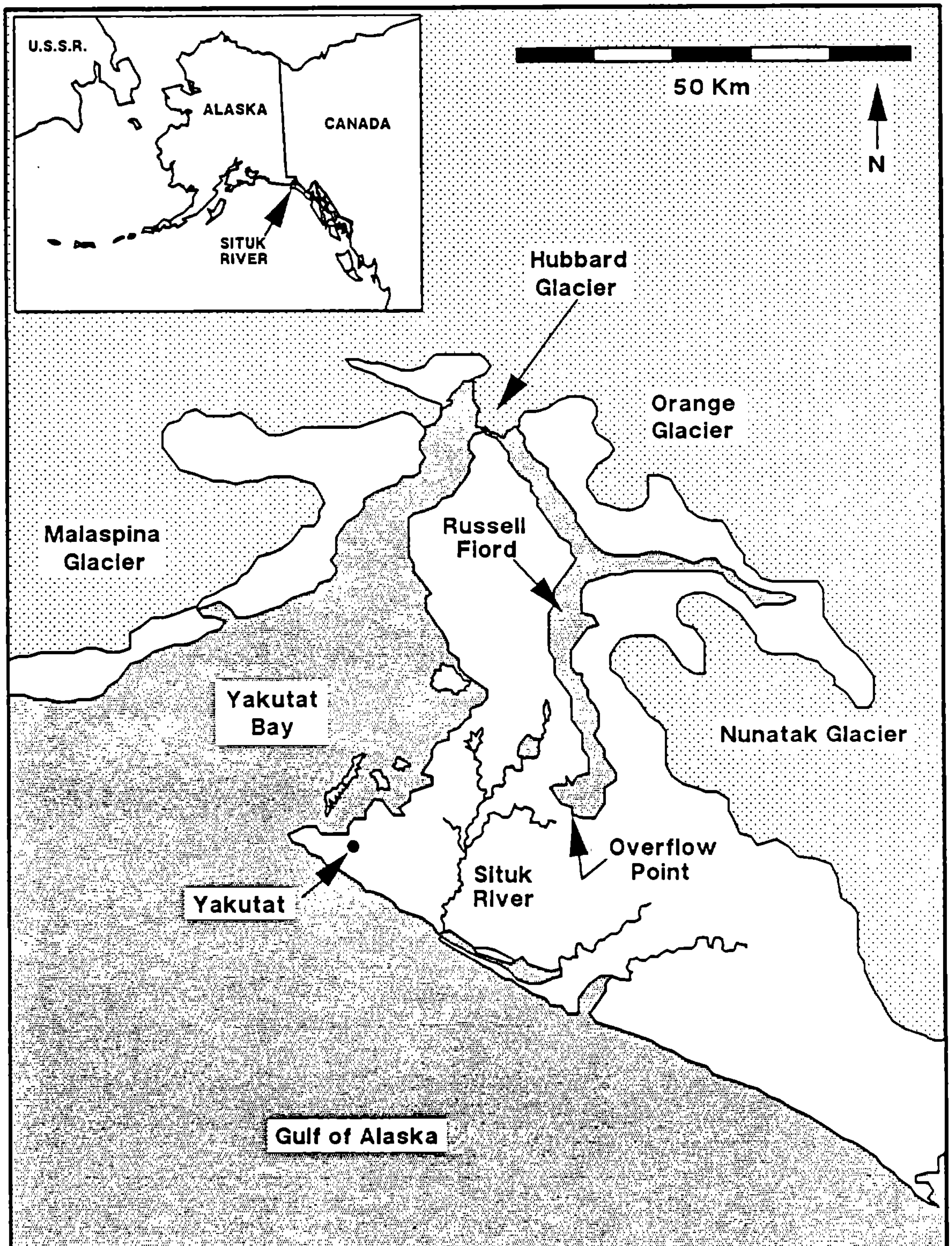

Figure 1. --Location of Hubbard Glacier, Russell Fiord, and Situk River near Yakutat, Alaska.

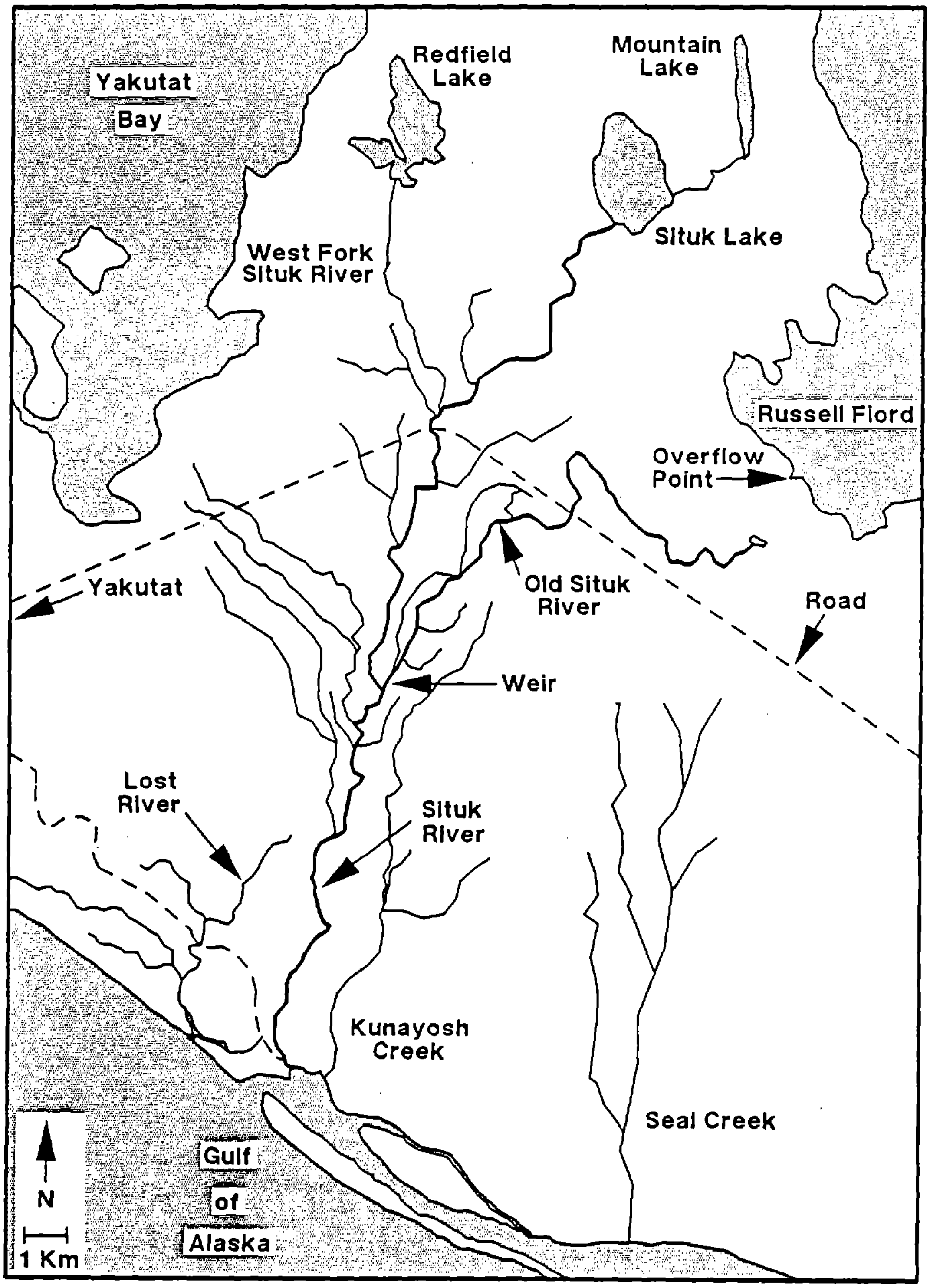

Figure 2.--Location of weir on Old Situk River.

Situk River is the former flood channel for overflow from Russell Fiord (Clark and Paustian 1989), trees within the floodplain are of relatively small size, and only a small amount of large woody debris is present in the channel to form good rearing habitat (Thedinga footnote 1).

METHODS

A V-shaped weir was constructed across Old Situk River approximately 200 m upstream from its confluence with the Situk River (Fig. 2). Two 1.5 m^2 fyke nets, each 3.8 m in length, were fished from the apex of the weir from 14 April to 2 July 1989. The weir was constructed of 6 mm^2 mesh Vexar[2] supported by 5.1 cm x 10.2 cm lumber secured by hose clamps to 3.2 cm diameter x 244 cm long steel pipe pounded partway into the substrate. Each fyke net was connected to a floating live box by a 10 cm diameter flexible hose. Fyke nets were fished 24 hours every day except for 2 days in May during a major freshet and for short daylight periods to allow passage of adult steelhead in mid-May and sockeye salmon in June.

Parr (> age 0) and smolts of all species and chinook fry (age 0) were enumerated daily; fry of all other species were enumerated every other day. All chinook fry and a subsample of up to 100 parr and 100 smolts of each species were measured for fork length (FL) daily. Every other day a subsample of 30 fry of each species (except chinook salmon) were measured for FL, and scale samples were taken from each subsampled species except Dolly Varden. Subsamples of 30 parr and 30 smolts of each species were also weighed to the nearest 0.1 g with an electronic Ohaus balance.

Body size and external characteristics of the salmonids were used to identify and separate fry, Parr, and smolts. Smolts were identified by changes in coloration including body silvering and darkening of fin tips (Trautman 1973). For some species, especially coho salmon, it was sometimes difficult to separate fast-growing fry from slow-growing Parr. Therefore, we set a size criterion to separate fry and parr (e.g., coho salmon 145 mm were classified as fry). An RBase computer program was later used to proportion the number of fry, parr, and smolts based on length frequency and ageing data.

'Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

To test the effectiveness of the fyke nets in capturing fish (trap efficiency), 45-50 coho smolts were marked by a fin clip and released approximately 200 m upstream of the weir on six different sampling periods in May and June. Four distinctive caudal fin clips were used; upper and lower tips were alternately clipped the first four marking periods followed by upper and lower v-notches the last two periods. The recapture rate of marked coho smolts caught in the fyke nets was used to estimate the percentage of all smolts captured. All recaptured smolts were combined for calculating trap efficiency because not all fish with a specific fin clip were recaptured before that clip was used again.

Trap efficiency ($\hat{E}$) was estimated by dividing the number of recaptured marked smolts by the number of marked smolts released upstream:

$$\hat{E} = R/M, \qquad (1)$$

where R is the number of marked fish recaptured and M is the number of marked fish released upstream.. Numbers of coho smolts were estimated by dividing the number of coho smolts caught by estimated trap efficiency:

$$\hat{N} = C/\hat{E}, \qquad (2)$$

where 3 is the estimated number of unmarked coho smolts migrating past the fyke nets and C is the total number of unmarked smolts in the catch. The confidence interval for $\hat{N}$ was determined by the bootstrap method (Efron and Tibshirani 1986) by resampling R from the binomial distribution (M, $\hat{E}$) and C from the binomial distribution ($\hat{N}$, $\hat{E}$). The percentile method was used to compute the confidence interval based on 200 bootstrap replications.

Water temperature was recorded hourly with an ENDECO thermograph, and stream stage was recorded daily with a staff gauge. Rearing area of Old Situk River was calculated by multiplying its mean width (Thedinga footnote 1) by its total length (determined from a U.S. Geological Survey (USGS) topographical map).

RESULTS

Over 110,000 juvenile salmonids were captured in the fyke nets in Old Situk River; 42% were fry, 45% were parr, and 13% were smolts (Table 1). Coho smolts were the most abundant fish, making up about 70% of the catch, and chinook and Dolly Varden smolts were the least abundant (10.1%).

A total of 123 of 293 (42%) coho smolts marked and released upstream of the weir were recaptured at the weir (Table 2). A total of 26,206 (95% confidence interval, 22,939-30,059) coho smolts were estimated to have migrated from Old Situk River (Table 3). If trap efficiency (42%) calculated for coho smolts is applied to other species captured at the weir, estimates of total numbers of fish increase by a factor of 100/42 or 2.4. Marked smolts returned slowly to the weir--some fish were not recaptured until 20 days after release, and fish were still being recaptured just 3 days prior to weir removal. Approximately 9 and 22% of marked smolts released upstream of the weir were recaptured at the weir within 1 and 2 weeks, respectively.

Based on the actual number of fish captured at the weir and the estimated rearing area of Old Situk River (288,559 m^2), the total yield of salmonids ($\geq$ age 1) was 19 fish/100 m^2 (Table 3). When the expanded number of fish based on trap efficiency was used, total yield became about 45 fish/100 m^2 (Table 3). Coho parr and smolts accounted for 91% of the total yield; parr made up 78% of the coho salmon yield. The yield of salmonid smolts was dominated by coho salmon (79%) while sockeye smolts accounted for 19%. The estimated number of chinook salmon wintering in Old Situk River was low (yield <0.1 smolt/100 m^2).

Migration timing varied by life stage within and between species (Table 1). Peak migration of coho parr occurred earlier (April) than coho fry or smolts (June)(Fig. 3). Most sockeye fry (96%) migrated in June, whereas sockeye smolt migration peaked in both April and June (Fig. 4). Sockeye smolts were approximately 10 mm larger (mean FL) during the peak migration in June when compared to fish migrating in April (Fig. 5). Nearly all pink (99%) and chum (91%) fry migrated in April and May, whereas most chinook fry (86%) migrated in June (Fig. 6). Steelhead and Dolly Varden parr had no obvious migration peak, whereas smolts from both species had peak migration periods in April and May (Fig. 7).

Table 1.--Number, peak migration period, and peak daily count of juvenile salmonids captured at Old Situk River weir, 14 April-2 July 1989.

Species	Stage	Number of fish	Peak migration period	Peak count
Coho	Fry	38,733[a]	June 2-5	1,832
Coho	Parr	39,038	April 18-30	2,854
Coho	Smolt	11,001	May 29-June 9	880
Sockeye	Fry	6,144	June 10-24	620
Sockeye	Smolt	2,578	April 17-25, June 2-5	218
Chinook	Fry	1,265	June 7-25	87
Chinook	Smolt	2	April 18-21	1
Pink	Fry	29,370[a]	April 24-May 7	2,066
Chum	Fry	142	May 5-31	22
Steelhead	Parr	2,020	April 18-June 20	80
Steelhead	Smolt	193	April 18-May 8	24
Dolly Varden	Parr	8,897	April 18-June 26	459
Dolly Varden	Smolt	97	May 14-18	23
Total		139,480[b]		

[a]Coho and pink fry were only counted every other day. On days when fry were not counted, number of fry were estimated by averaging the counts for days prior to and after the missing day.

[b]Actual number of fish captured was 110,022; see coho and pink fry estimates.

Table 2. --Number of coho smolts fin clipped and released above Old Situk River weir and recaptured at the weir, 1989.

Release date	Number fin clipped	Fin clip	Number recaptured
May 13, 24	50, 49	Upper caudal	50[a]
May 19, June 1	50, 50	Lower caudal	32[a]
June 9	45	Upper caudal notch	23
June 16	49	Lower caudal notch	18
Total	293		123

[a]Date of release of some recaptured fish was undetermined because the same mark was used twice during the sampling season.

Table 3. --Yield of juvenile salmonids captured at Old Situk River weir and expanded number of juveniles based on trap efficiency (42%). Rearing area of Old Situk River is 288,559 m^2.

	Actual		Expanded	
Species/stage	Number of fish	Yield (no./100 m^2)	Number of fish	Yield (no./100 m^2)
Coho smolt	11,001	3.8	26,206	9.1
Coho parr	39,038	13.5	92,993	32.2
Sockeye smolt	2,578	0.9	6,141	2.1
Steelhead parr	2,020	0.7	4,812	1.7
Steelhead smolt	193	0.1	460	0.2
Chinook smolt	2	<0.1	5	<0.1
Total	54,832	19.0	130,617	45.3

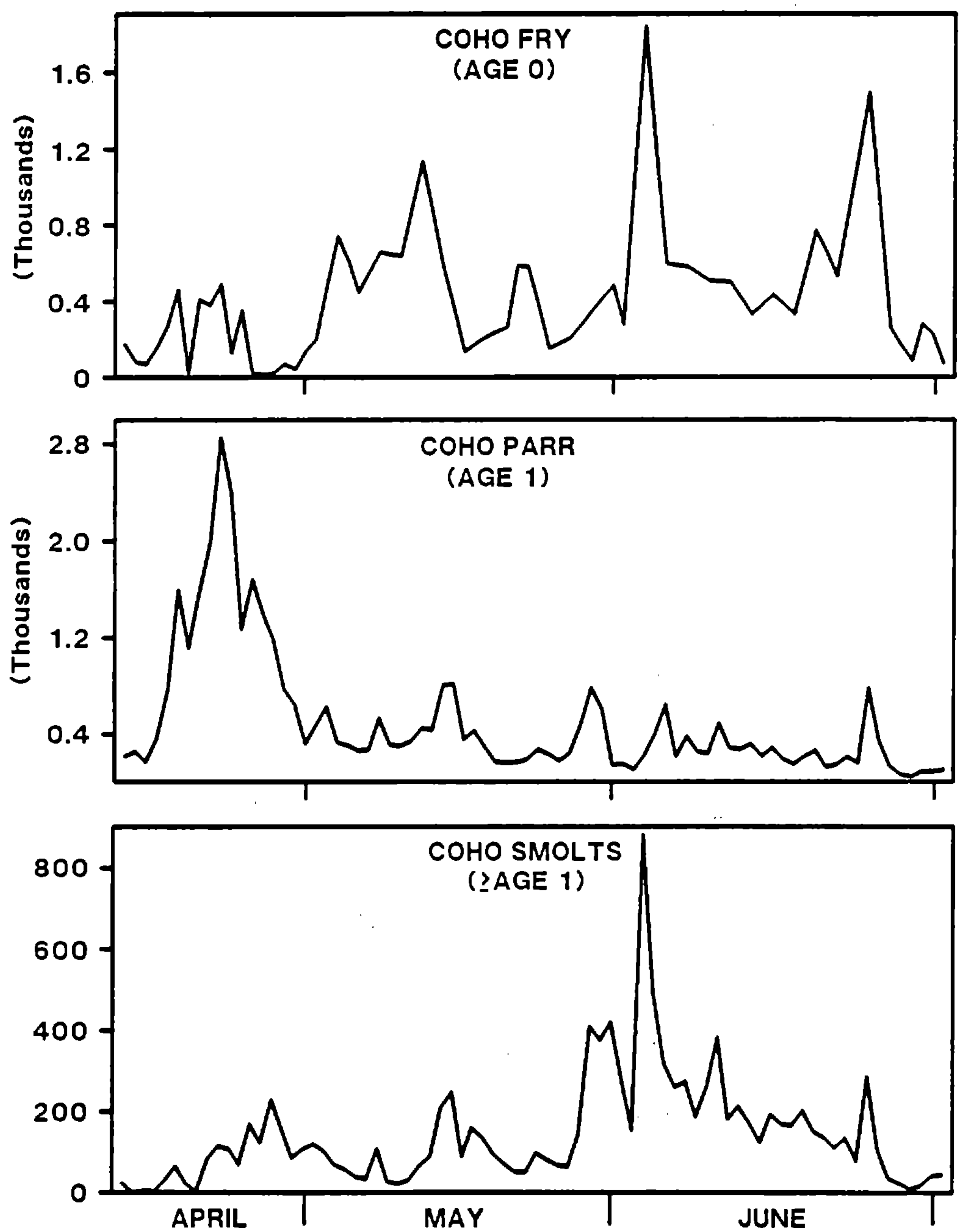

Figure 3.--Daily catch of coho salmon at Old Situk River weir, 1989.

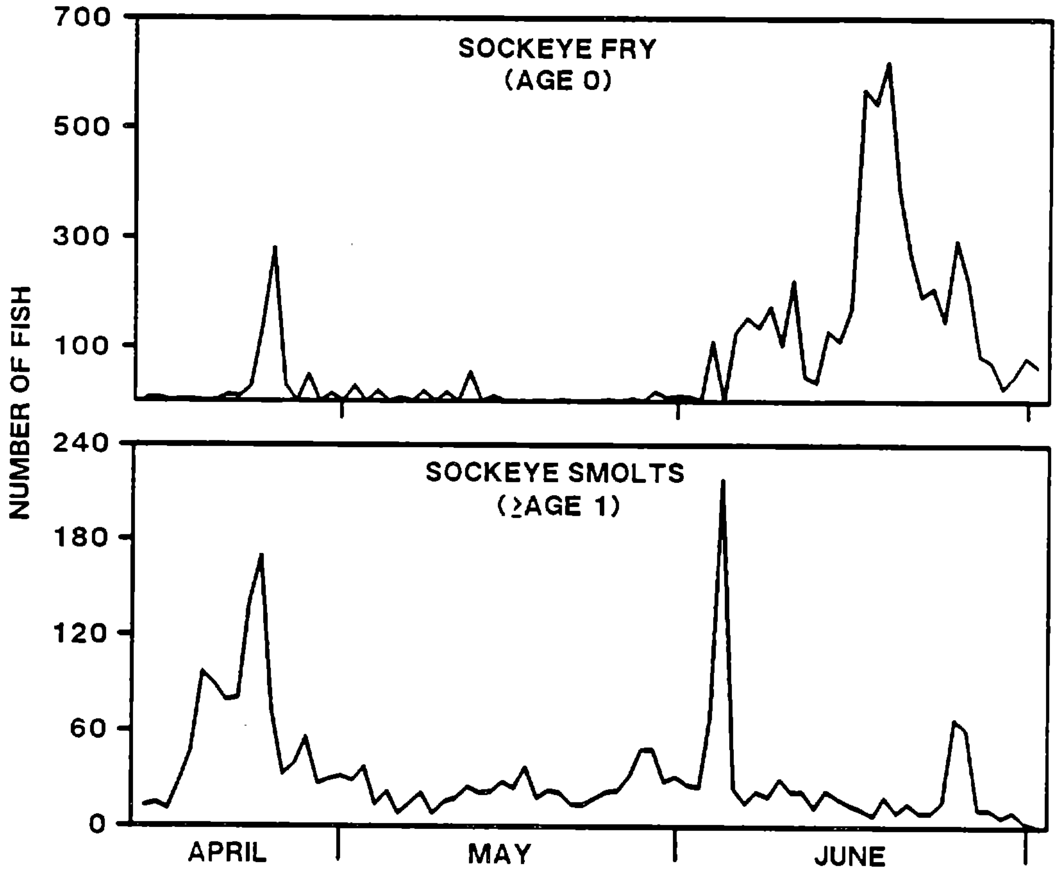

Figure 4.--Daily catch of sockeye salmon at Old Situk River weir, 1989.

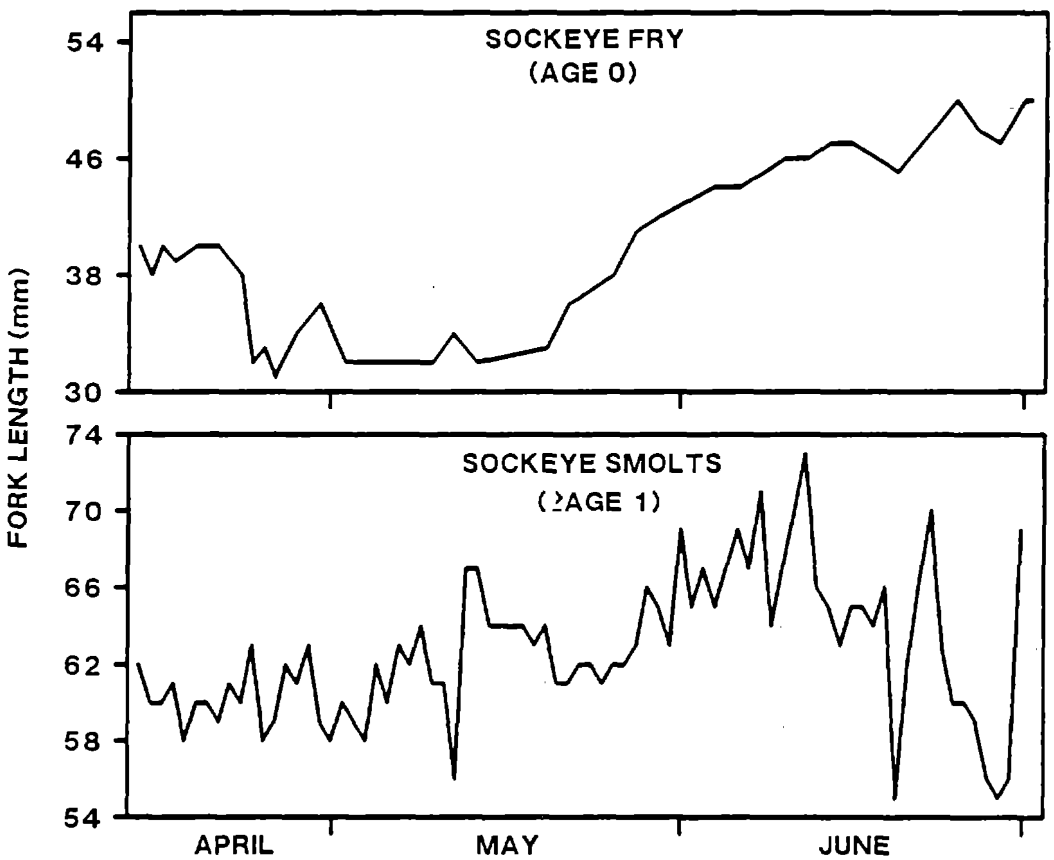

Figure 5.--Daily mean fork length of sockeye salmon at Old Situk River weir, 1989.

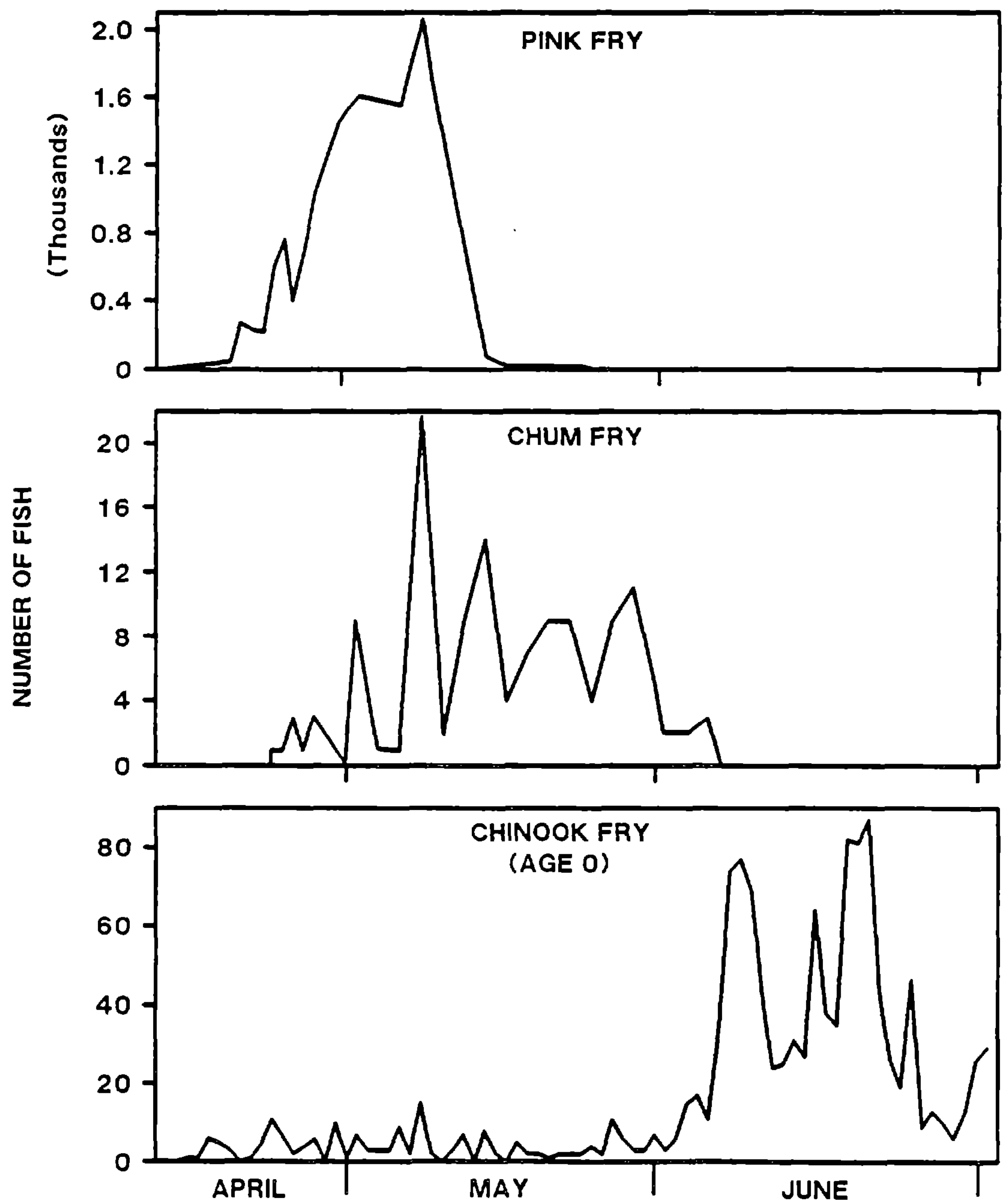

Figure 6.--Daily catch of pink, chum, and chinook salmon at Old Situk River weir, 1989.

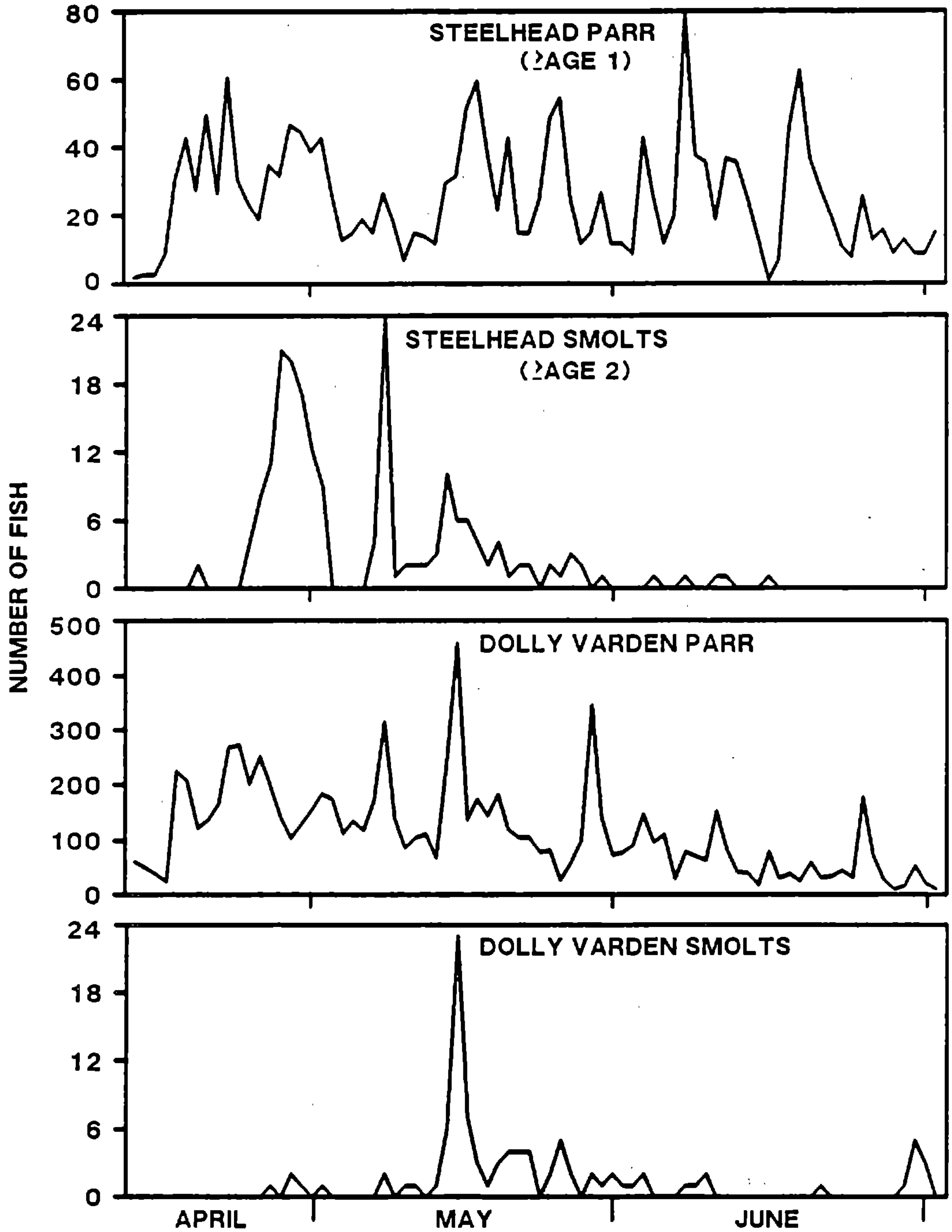

Figure 7. --Daily catch of steelhead and Dolly Varden at Old Situk River weir, 1989.

Daily mean FL of all juveniles except coho fry and sockeye smolts increased steadily throughout the study (Figs. 5, 8-11). Mean FL of coho fry decreased from April through May because of an early emigration of large fry (mean FL 44 mm); however, FL of fry increased sharply in June (Fig. 8). Mean FL of sockeye smolts increased until mid-June and then decreased until early July (Fig. 5). In April and May, when most pink (99%) and chum (91%) fry migrated, mean FL was 34 and 39 mm, respectively (Fig. 9). In June, mean FL increased to 39 and 44 mm for pink and chum salmon fry, respectively. From April to June, the daily mean FL of chinook fry increased from 40 mm to almost 70 mm (Fig. 9). The largest steelhead parr (mean FL 78 mm) and smolts (mean FL 170 mm) migrated in June (Fig. 10), whereas the largest Dolly Varden parr (mean FL 90 mm) migrated in late June and the largest smolts (mean FL 250 mm) migrated in May (Fig. 11). Overall mean FL and weight of each species by age is summarized in Table 4.

Age composition varied among species captured (Table 5). For coho salmon and steelhead, age-l fish were the most abundant (56 and 77%, respectively), while age-0 fish dominated catches of sockeye and chinook salmon (70.3% and 99.8%, respectively). Among smolts, most coho and sockeye salmon were age 1, whereas most steelhead were age 3 (95, 99, and 47%, respectively) (Table 6).

Daily mean water temperature increased from 5 to 12°C during the study (Fig. 12), and stream stage varied from approximately 40 cm to nearly 80 cm; however, most variation in stream stage resulted from a freshet on 14 May when water depth rose 32 cm. Excluding the freshet, stream stage ranged from only 38 to 50 cm. Peaks in the migrations of coho fry and smolts, sockeye smolts, chinook fry, and steelhead parr corresponded to the sharp increase in water depth in early June (Figs. 3, 4, 6, 7). The rapid increase in water temperature at the end of April corresponded to peaks in the migrations of coho parr, sockeye fry, pink fry, and steelhead smolts (Figs. 3, 4, 6, 7).

DISCUSSION

The expanded estimate of juveniles based on trap efficiency probably overestimates the actual number of fish that migrated from Old Situk River. Marked smolts released upstream of the weir were probably more susceptible than other fish to predation or delays in their migration because of stress from handling. Old Situk River has relatively little large woody debris; therefore, pools and cover are limited, and predation, especially just above the weir where

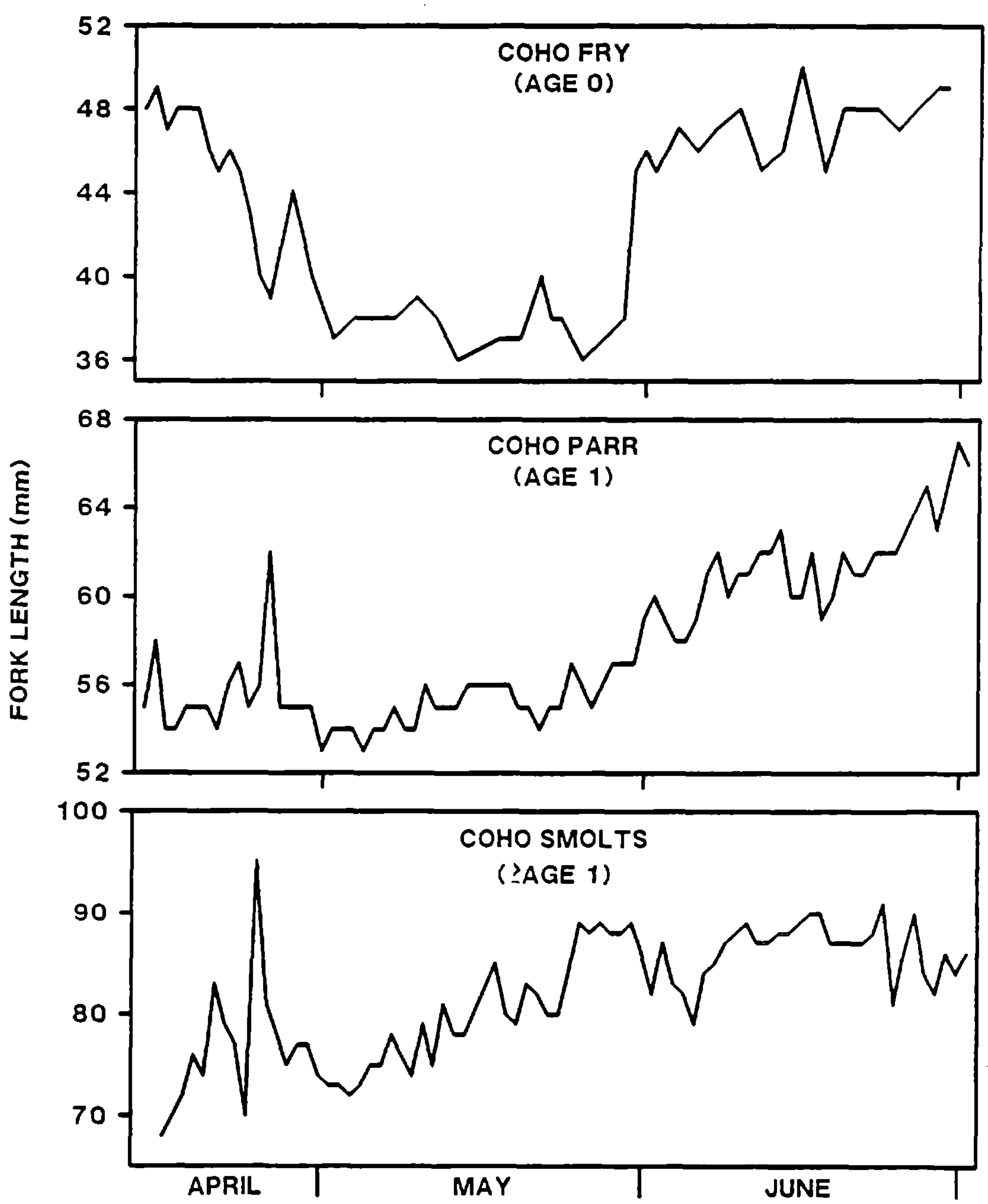

Figure 8.--Daily mean fork length of coho salmon at Old Situk River weir, 1989.

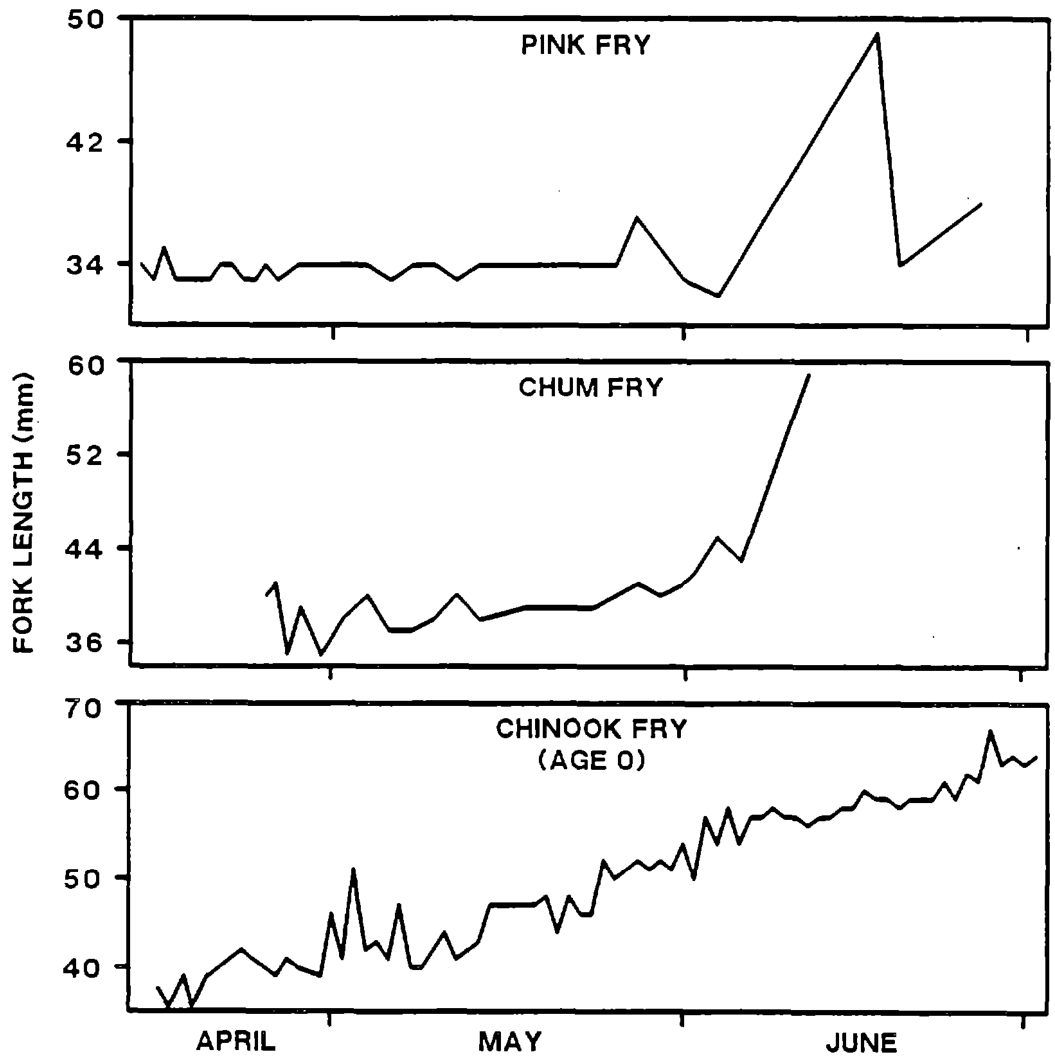

Figure 9.--Daily mean fork length of pink, chum, and chinook salmon at Old Situk River weir, 1989.

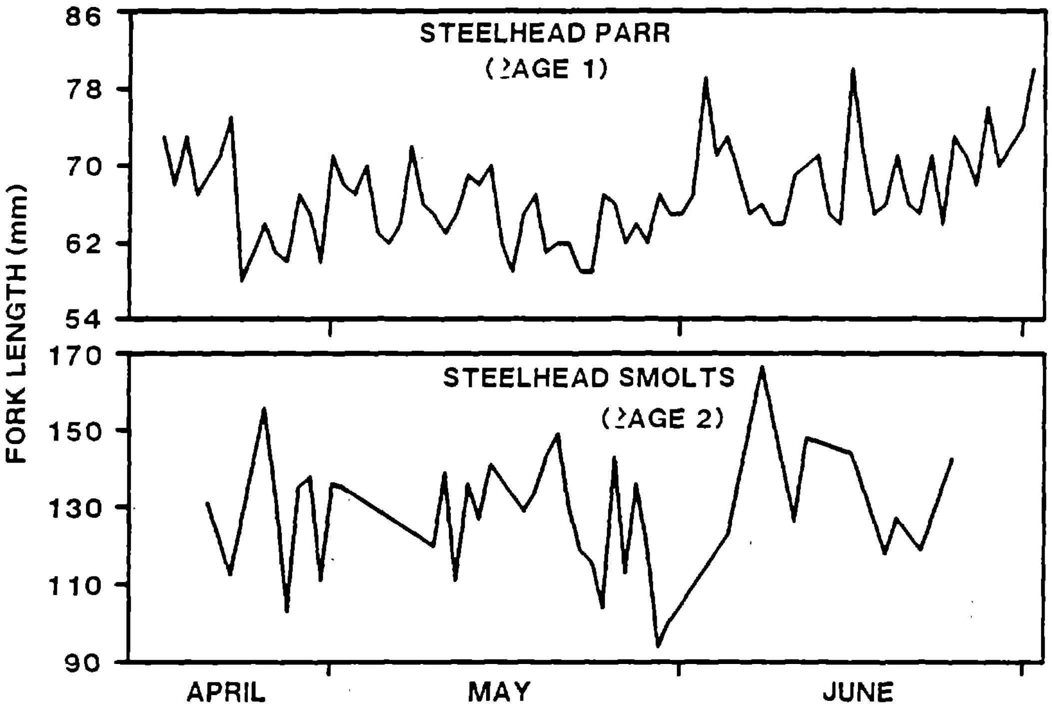

Figure 10. --Daily mean fork length of steelhead at Old Situk River weir, 1989.

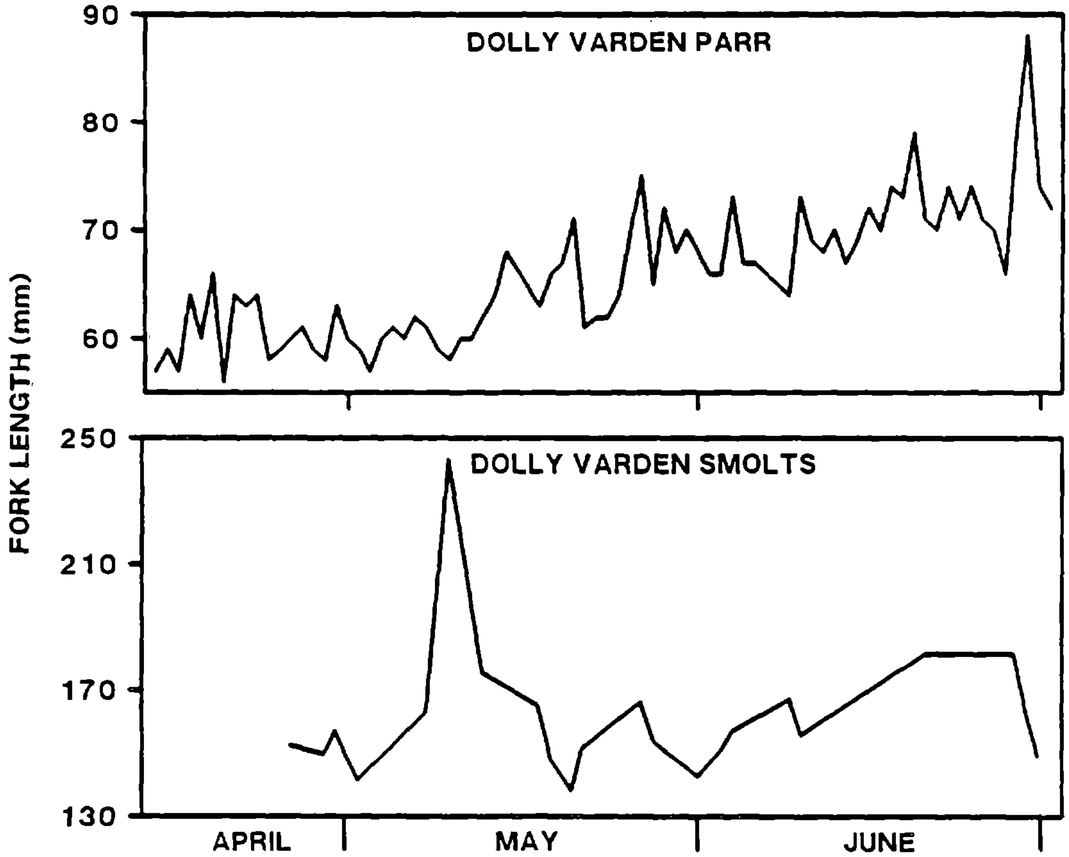

Figure 11.--Daily mean fork length of Dolly Varden at Old Situk River weir, 1989.

Table 4.--Mean length and weight of juveniles captured at Old Situk River weir, 14 April-2 July 1989.

Species	Age (years)	Fork length (mm)	SD	Weight (g)	SD
Coho	0	46	8	1.6	0.5
Coho	1	69	14	4.0	2.5
Coho	2	105	10	13.7	3.7
Coho	3	153	0	34.3	0
Sockeye	0	46	6	1.2	1.2
Sockeye	1	62	6	2.5	0.9
Sockeye	2	94	4	6.9	1.4
Chinook	0	56	7	2.3	0.8
Chinook	1	84	5	---	---
Pink	0	34	1	0.3	0.1
Chum	0	39	3	0.5	0
Steelhead	1	63	9	3.0	1.4
Steelhead	2	91	11	9.0	4.0
Steelhead	3	124	14	21.2	6.0
Steelhead	4	157	11	34.9	7.4
Dolly Varden	[a]	66	13	2.8	5.0
Dolly Varden	[b]	155	30	32.2	0

[a]Parr not aged.

[b]Smolt not aged.

Table 5.--Age composition of juvenile salmonids caught at Old Situk River weir, 14 April-2 July 1989, extrapolated from number of fish aged.

Species	Number of fish aged	Age in years (%) 0	1	2	3	4
Coho	276	43.3	56.0	0.7	<0.1	0.0
Sockeye	126	70.3	29.5	0.2	0.0	0.0
Chinook	44	99.8	0.2	0.0	0.0	0.0
Steelhead	152	0.0	77.7	14.7	5.4	2.2

Table 6.--Age composition of smelts captured at Old Situk River weir, 14 April-2 July 1989, extrapolated from number of fish aged.

Species	Number of fish aged	Age in years (%)			
		1	2	3	4
Coho	61	94.6	5.4	<0.1	0.0
Sockeye	84	99.3	0.7	0.0	0.0
Steelhead	152	0.0	29.8	47.1	23.1

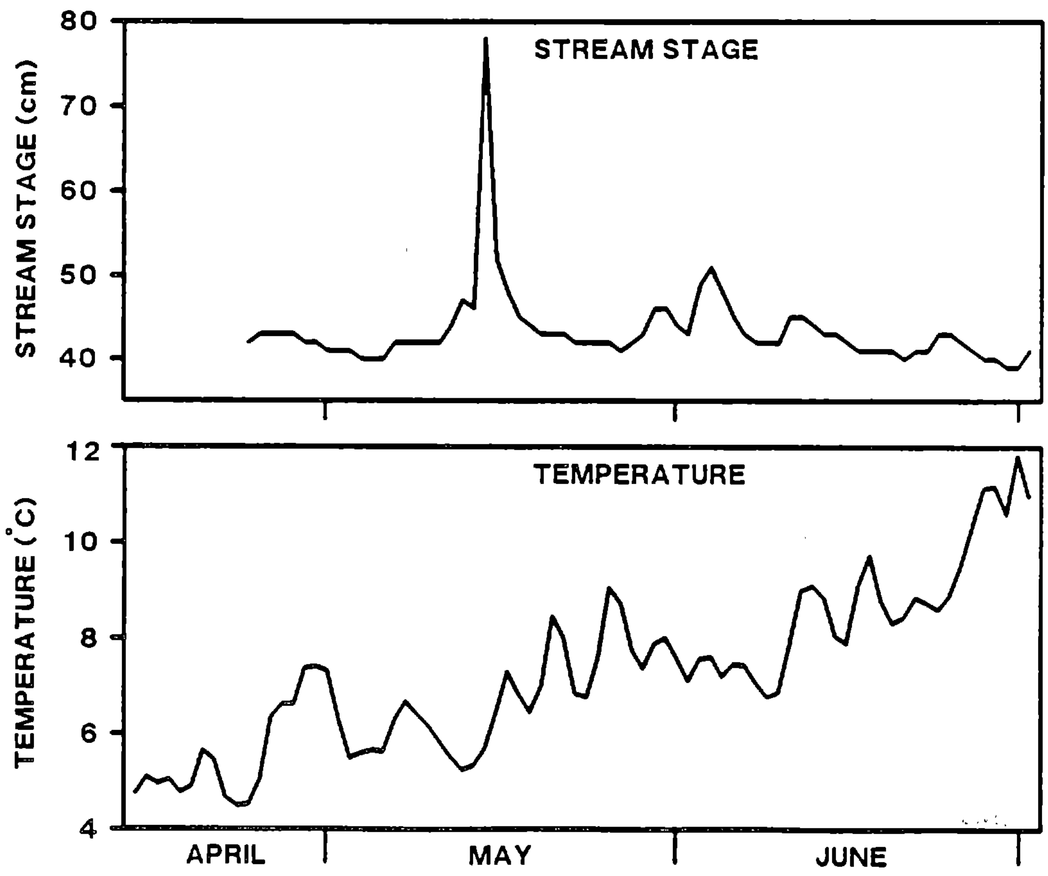

Figure 12.--Daily stream stage and daily mean water temperature of Old Situk River, 1989.

smolts tended to accumulate, may be-higher than in other areas of the river or main stem. Smolts could also have passed through the weir during the day when the fyke nets were opened to allow passage of adult steelhead and sockeye salmon. Undoubtedly, by the end of the study all marked smelts had not migrated from Old Situk River because one marked smolt was recaptured just 3 days prior to removal of the weir.

Mean length of coho fry (44 mm FL) was unusually large in Old Situk River in April. Adult coho salmon in the Situk have an extensive spawning period beginning in September and extending into winter. This probably results in a wide range in emergence timing and, hence, a wide range in size of coho fry. Because Old Situk River is spring fed, extremes in water temperature are less pronounced, and overall annual fluctuations in temperature are less severe than those observed in lake or runoff-fed streams. The large size of coho fry in late April compared to May indicates that these fish may have been the progeny of early spawning adults and eggs that were incubated in relatively warm spring water, resulting in early emergence and fast-growing fry. The other extreme (late spawning adults and late emerging fry) could result in very small fry by winter. These small fry may not form an annulus and the next spring could be mistaken for large fry when they are actually age-1 parr.

The proportions. of age-l coho (95%) and sockeye (99%) smolts in Old Situk River differ from those found in other Alaskan streams, whereas age composition for steelhead smolts is similar. For coho salmon, Thedinga and Koski (1984) and Crone and Bond (1976) reported that age-l smolts comprised only 20 and 27% of the smolt population in two Southeast Alaskan streams. The proportion of freshwater age-l coho adults caught in the Situk River commercial fishery was approximately 50% (Riffe et al. 1987). Age composition of coho salmon in Old Situk River is typical of the more southerly streams of the Pacific Northwest where nearly all coho smolts are age 1 (Shapovalov and Taft 1954; Niska and Willis 1963). For sockeye salmon, most rear for 1-2 years in lakes (Foerster 1968). The proportion of freshwater age-l sockeye adults captured in the Situk River commercial fishery (67%) (Riffe et al. 1987) was much lower than the proportion of age-l sockeye smolts (99%) found in Old Situk River. In Southeast Alaska, some sockeye salmon populations have individuals that migrate to sea soon after emergence (sea-type) or rear in river habitats (river-type) for one or more years (Heifetz et al. 1989; Wood et al. 1987). Sockeye smelts from Old Situk River are typical of river-type sockeye salmon found in glacial systems such as the Taku and Stikine Rivers (Murphy et al. 1989; Wood et al. 1987). The high proportion of age-1 coho and sockeye smolts is probably a result of a water temperature regime that is conducive to early emergence and rapid growth. For steelhead in Old Situk River, age-3 smolts were most abundant, followed by age-2 and -4 smolts; this pattern is similar to that found in other Southeast Alaskan streams (Jones 1977).

Yield of juvenile salmonids from Old Situk River indicates that it is an important wintering area for several salmonid species. Based on trap efficiency computations, the yield of coho smolts in Old Situk River (9.1 smolts/100 m^2) was similar to other Alaskan streams where coho smolt yields ranging from 5 smolts/100 to 32 smolts/100 m^2 have been reported (Crone and Bond 1976; Thedinga and Koski 1984). The large migration of coho parr suggests that after wintering in Old Situk River, parr move to the main stem to rear and probably emigrate as smolts. If coho parr that migrated from Old Situk River became smolts that year, then coho smolt yield (based on actual count) would increase from 4 smolts/100 to 17.3 smolts/100 m^2 and would be similar to the estimates of Thedinga and Koski (1984). If the expanded number of coho smolts and parr are combined, then the estimated yield of 41.3 smolts/100 m^2 would be similar to smolt yields (mean 42 smolts/100 m^2) reported by Chapman (1965) for three Oregon streams.

Although wintering of sockeye salmon in non-lake habitats is uncommon, age-l sockeye salmon were the second most abundant group of smolts enumerated from Old Situk River. Thedinga et al. (1988) suggested that sockeye salmon wintered in side sloughs and tributary beaver ponds of the Taku River, Alaska. Sockeye salmon that rear in rivers (called river-type) occupy such habitats for at least 1 year (Wood et al. 1987), but little is known about where they winter. About one-half of Old Situk River consists of "slough" habitat; that is, areas that are usually braided channel segments that have placid flows and are controlled by shallow groundwater. These areas are probably used by sockeye for wintering prior to emigrating as smolts. Sockeye fry that emigrated in June may have been age-0 smolts (sea-type). Adult sockeye salmon sampled from Old Situk River were predominately sea-type (94%) based on scale analysis[3]. Murphy et al. (1988) reported similar timing in the migration of sea-type sockeye smelts in the Taku river.

'Alaska Department of Fish and Game. 1990. ADF&G, Commercial Fisheries Division Scale Laboratory, Douglas, AK 99824. Unpubl. data.

CONCLUSIONS

Flooding from Russell Lake will most likely impact fish habitat of the Situk River. Estimated discharge of flood waters into Situk River will be about 220 m^3/s compared to an average flow of only 10-15 m^3/s (Mayo 1988). Such high flows will destroy some of the riparian forest, create debris dams which may intensify flooding, and cause sudden outwashes of debris (Paul 1988). High flows will also cause erosion of soil and sediments resulting in increased turbidity of the river (Mayo 1988). Water temperatures will most likely decrease as a result of glacial runoff into Russell Lake. These changes will affect both spawning and rearing fish in the Situk River. Flood waters will cause Old Situk River and a portion of the Situk River to become a cool, fast, turbid river with spawning and rearing limited to stream margins.

If flooding occurs during spawning in Old Situk River, most fish will be displaced or lost downstream, and eggs deposited in the gravel will most likely be either scoured from the streambed or buried in sediment. Flooding in Old Situk River will mostly affect coho, sockeye, and pink salmon populations; chinook salmon will be least affected. Flooding could ultimately result in the loss of unique races such as sea-type sockeye salmon in Old Situk River and age-0 chinook salmon from the main stem. Eventually, the river will stabilize and new habitat will become available. Because a similar flooding event has occurred several times in the past--the most recent event ending approximately 150 years ago (Mayo 1988) --the river may eventually regain its former productivity. In fact, a major sockeye salmon system could ultimately result from the formation of Russell Lake.

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