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# Juvenile Salmonid Densities and Habitat Use in the Main-stem Situk River, Alaska, and Potential Effects of Glacial Flooding

## Abstract

Densities and habitat use of juvenile coho salmon (*Oncorhynchus kisutch*), sockeye salmon (*O. nerka*), steelhead (*O. mykiss*), and Dolly Varden (*Salvelinus malma*) were determined in the main-stem Situk River, Alaska. Three habitat types (channel edges, willow edges, and debris pools) were sampled at two downstream sites (lower river) and at two upstream sites (upper river) biweekly from May to September and once in November 1989. For most species, fry (age 0) most often used channel edges with little cover, whereas parr (age $\geq 1$) almost exclusively occupied willow edges and debris pools. Within the same habitat types, densities were significantly greater for most species and life-history stages in the upper than in the lower river; steelhead parr, with densities similar in like habitats in the upper and lower river, were a notable exception. Peak fry densities (fish/100 $m^2$) were 2,331 coho, 155 steelhead, and 14 sockeye, whereas peak parr densities were 281 coho, 82 steelhead, and 44 Dolly Varden. Mean length of fry and parr of all species was greater in the lower river than in the upper river. With baseline information from this study, fisheries managers can identify strategies to restore fish and habitat that could be impacted by flooding in the Situk River. Hubbard Glacier is expected to advance and dam Russell Fiord by the year 2000, and overflow from the fiord will flood the Situk River, drastically altering fish rearing habitat.

## Introduction

Fisheries of the Situk River in Southeast Alaska will be altered when the Hubbard Glacier advances and dams Russell Fiord, because overflow from the resulting "Russell Lake" will flood the river (Figure 1) (Clark and Paustian 1989). Closure of Russell Fiord by Hubbard Glacier is probable by the year 2000 (Trabant *et al.* 1991). Damming of Russell Fiord and flooding of the Situk River occurred most recently in the mid-1800s (de Laguna *et al.* 1964). The Situk River currently supports commercial, sport, and subsistence fisheries for Pacific salmonids valued at \$2-3 million annually. Knowledge of the life history and habitat use of juvenile salmonids in the main-stem Situk River is essential to predict effects of flooding on rearing salmonids.

Limited life-history information is available on juvenile coho salmon (*Oncorhynchus kisutch*), sockeye salmon (*O. nerka*), steelhead (*O. mykiss*), and Dolly Varden (*Salvelinus malma*) in the Situk River. Downstream migrants have been enumerated from Old Situk River, a major tributary of the Situk River (Figure 1) (Thedinga *et al.* 1991). Migration timing, size, and salinity tolerance of juvenile sockeye in the Situk River estuary were examined by Heifetz *et al.* (1989). Extensive life history information on juvenile chinook salmon (*O. tshawytscha*) in the Situk River has been described by Johnson *et al.* (1992).

Our objectives were to examine densities and habitat use of juvenile coho and sockeye salmon, steelhead, and Dolly Varden in the Situk River and to predict some of the potential effects of flooding on fish populations and rearing habitat. This baseline information will enable fisheries managers to identify strategies to restore fish and habitat that could later be impacted by flooding.

## Study Area

The Situk River, 18 km southeast of Yakutat, Alaska (Figure 1), is a clear, fourth-order, coastal stream that contains stocks of five Pacific salmon (*Oncorhynchus* spp.), steelhead, cutthroat trout (*O. clarki*), and Dolly Varden. The main stem is 35 km long from the outlet of Situk Lake (315 ha) to the ocean. Average summer flow is approximately 6 $m^3/s$ (Clark and Paustian 1989). Tides twice daily influence the lower 3.5 km of the Situk River before it enters the estuary. At high tide the lower portion of the river, referred to as lower river, deepens, water velocity subsides, and salinity increases but remains low (mean bottom salinity

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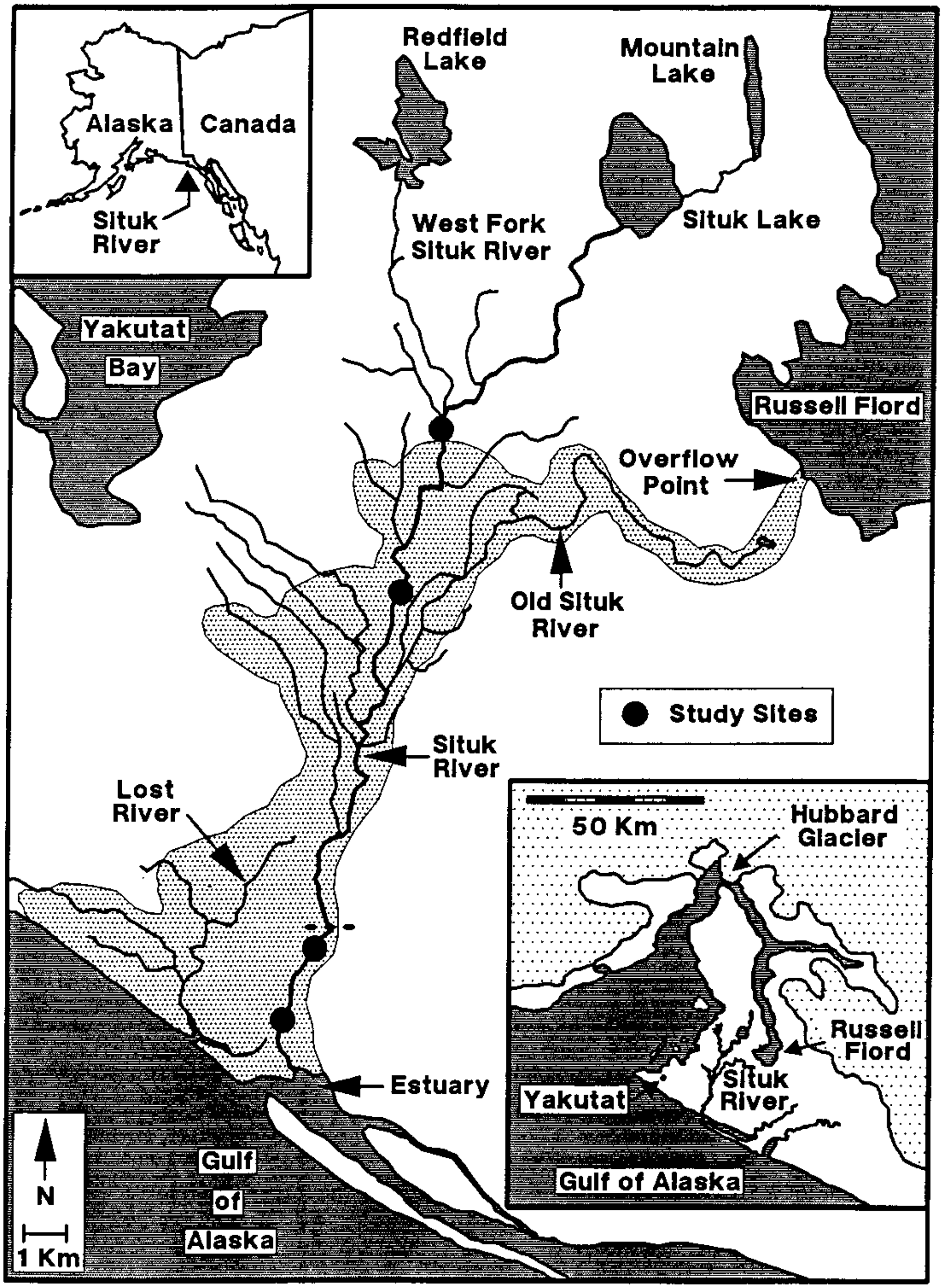

Figure 1. Sites sampled for juvenile salmonids in the main-stem Situk River, Alaska, 1989. Stippled area on main stem represents predicted flood zone. Dashed line across main stem represents upper boundary of tidal influence and also separates upper river from lower river. In lower inset, arrow from Hubbard Glacier points to location of potential ice dam.

$<5.0$‰) (Heifetz *et al.* 1989). The remainder of the main stem is not affected by tides and is considered the upper river. The river has two major third-order tributaries: Old Situk River is 20 km long, originates at a small pond, and has an average summer flow of 1.5 m$^3$/s (Thedinga *et al.* 1991); and West Fork Situk River is 10 km long, flows out of Redfield Lake (200 ha), and has an average summer flow of about 1 m$^3$/s.

## Methods

We sampled two sites in the lower river and two sites in the upper river (Figure 1) biweekly from 10 May to 22 September 1989 to estimate fish density and habitat use. These sites were sampled again on 30 November 1989 for relative abundance and late fall distribution, but we did not estimate fish density. Sites were selected based on similarity of habitats (i.e., like habitats existed among all sites) and ease of accessibility. Except in November, we sampled three principal habitat types at each site: three channel edges (main-channel edge with little or no overhanging vegetation); one willow edge (main-channel edge with dense overhanging willow (*Salix* sp.) or other vegetation and submerged roots); and one debris pool (pool containing large woody debris—pieces $\geq 10$ cm diameter and 1 m long). Other habitat in the main stem was mostly main-channel thalweg, probably little utilized by rearing salmonids (Murphy *et al.* 1989). In November we sampled only willow edges and debris pools.

Fish were caught in the different habitats with either seines or minnow traps. Fish in channel edges were caught with a pole seine (5.4 m long, 1.5 m deep, and 6-mm mesh) pulled against the current parallel to shore for 20 m (area seined = 74 m$^2$). Seines could not be used in willow edges or debris pools because they snagged on submerged roots and large woody debris (LWD). In willow edges and debris pools, fish were caught with minnow traps (spaced 3 m apart) baited with salmon roe; 7 traps were set in a 21-m section of willow edge and up to 15 traps were set in debris pools (area of pools was larger than willow edges and required more traps to saturate available habitat). All traps were set during the day.

We used the removal method (Zippin 1958) to estimate fish populations within habitat types. Three passes with a seine were usually made per channel edge; if no fish were caught in the first pass, no further seining was done. In willow edges and debris pools, traps were set for 40 min, retrieved, emptied of fish, rebaited, and set again in the same location for 40 min. Traps were set at least three times. If the catch on the third set was not substantially reduced from the second set, additional sets were made until catch was reduced from the previous set. Fish caught in each seine or trap set were kept in separate containers. Immigration and emigration were assumed to be negligible during sampling. We placed the first minnow trap 3 m upstream from the lower boundary of willow edges and debris pools to limit attracting fish from downstream areas. Total catch was used in the analysis instead of the estimated $\hat{N}$ if the estimated probability of catch $\hat{q}$ was $\leq 0.20$. Fish density in each habitat type was computed by dividing the population estimate by the area seined or trapped. In November, minnow traps were set once in willow edges and debris pools and retrieved after 24 h.

Amount of available habitat was measured at each habitat type at each site during low flow and in the lower river at low tide. Linear transects perpendicular to streamflow were established at 3-m intervals in each habitat type. Total area of willow edges and of debris pools was estimated by multiplying mean width (measured at transects) by total length of habitat. For willow edges, area was based on the distance willow vegetation protruded over the river; for debris pools, area was based on the length and width of the part of the pool containing LWD. Water depth was measured at one-quarter, one-half, and three-quarters of the distance across each transect of each habitat type. Water velocity was measured at one-quarter, one-half, and three-quarters of the distance across the lower, middle, and upper transect of each habitat type. Total pieces of LWD were counted in each habitat type. In the lower river, water temperature was measured every 2 h with a continuous recording Endeco® thermograph from June through November 1989. In the upper river, water temperature was measured with a Datapod® at a U.S. Geological Survey gauging station about 1 km downstream from the confluence with West Fork Situk River. A more detailed description of habitat characteristics has been provided by Johnson *et al.* (1992).

Each sampling period, all sockeye, steelhead, and Dolly Varden, and a subsample of coho (minimum 100 fish) caught at each site were measured for fork length (FL), and scale samples were taken from up to 25 fish of each species to determine age, except Dolly Varden, which have scales too small and difficult to remove. In this report, fry are fish that had reared less than a year in fresh water (age 0), whereas parr had reared one or more years in fresh water (age $\geq 1$). Because assessment of rearing fish and habitat was the primary objective, smolts were omitted from analyses.

Vulnerability to capture in seines or minnow traps was assumed equal for most species and life-history stages. Exceptions were Dolly Varden fry and sockeye. Because few Dolly Varden fry were caught, they were omitted from analyses. Small size of fry and use of substrate interstices probably made Dolly Varden less vulnerable to capture than other fry. Few sockeye fry and no sockeye parr were caught in willow edges or debris pools, probably because they are primarily zooplankton feeders and thus not attracted to the bait (salmon roe) inside the minnow traps. For all other species and life stages, however, it was assumed that we were effectively removing most fish in all three habitat types, regardless of method of capture.

Within the upper and lower river sites, differences in mean fish densities by habitat type were examined by Friedman's tests (Zar 1974); sampling periods served as blocks and habitat types as treatments. Differences in mean fish densities between the same habitat types in the upper and lower river sites were examined by Mann-Whitney tests (Zar 1974); in like habitats, mean densities were compared between the upper and lower river for fry and parr of each species. Differences in mean fork length of each species and life stage between the upper and lower river sites (all sampling periods and habitat types combined) were examined by t-tests (Zar 1974).

## Results

### Habitat Characteristics

Water depth, velocity, and cover differed among habitat types. Average depth was greatest in debris pools (1.2 m) and least in channel edges (0.3 m). Average water velocity was greatest in willow edges (15 cm/s) and least in debris pools (10 cm/s). Cover was scarce in channel edges but was abundant in debris pools as LWD (range = 8-25 pieces) and in willow edges as overhanging vegetation and submerged roots.

Mean daily water temperature at the upper and lower river sites ranged between 9 and 15°C from early June to September and peaked in mid-July. Summer water temperatures were consistently 1-2°C warmer in the upper river than in the lower river, probably because of the warming influence of Situk Lake. Water temperature dropped to 1.0-2.0°C by late November.

### Life-History Stage

Fry dominated the catch during most sampling periods at both the upper river and lower river sites (Figure 2). All sockeye were fry, but nearly all Dolly Varden were parr. Coho parr dominated the catch (60%) only in debris pools in the lower river in May. All steelhead were parr in May and June and 54-99% fry thereafter, as fry emerged from the gravel beginning in July. Coho fry were caught from May through November, most sockeye fry from May through July, and steelhead fry from late July through November. Coho, steelhead, and Dolly Varden parr were caught from May to November.

### Fry Densities and Habitat Use

Mean density (fish/100 $m^2$) of coho fry differed significantly ($P < 0.05$) among habitat types at the lower river sites but was similar ($P > 0.05$) among habitats at the upper river sites (Figure 3). Lower river mean densities were greater in willow edges (range = 0-471) and debris pools (0-382) than in channel edges (0-82). In the upper river, mean densities ranged from 2 to over 1,400 coho in all habitat types. Fry density peaked earlier (May and June) in channel edges than in willow edges or debris pools (July). After July, coho fry density declined steadily at both the upper and lower river sites.

Mean density of steelhead fry did not differ significantly ($P > 0.05$) among habitat types at either the upper or the lower river sites; however, most sockeye fry were caught in channel edges. Sockeye (data not shown) and steelhead (Figure 3) fry densities peaked in late May and late July, respectively, in channel edges at both the upper and the lower river sites.

Within the same habitat types, mean densities (fish/100 $m^2$) of coho and steelhead fry were significantly ($P < 0.10$) greater at the upper than at the lower river sites (Figure 3), whereas sockeye fry densities (data not shown) were similar ($P > 0.10$). Peak fry densities were 2,331 coho,

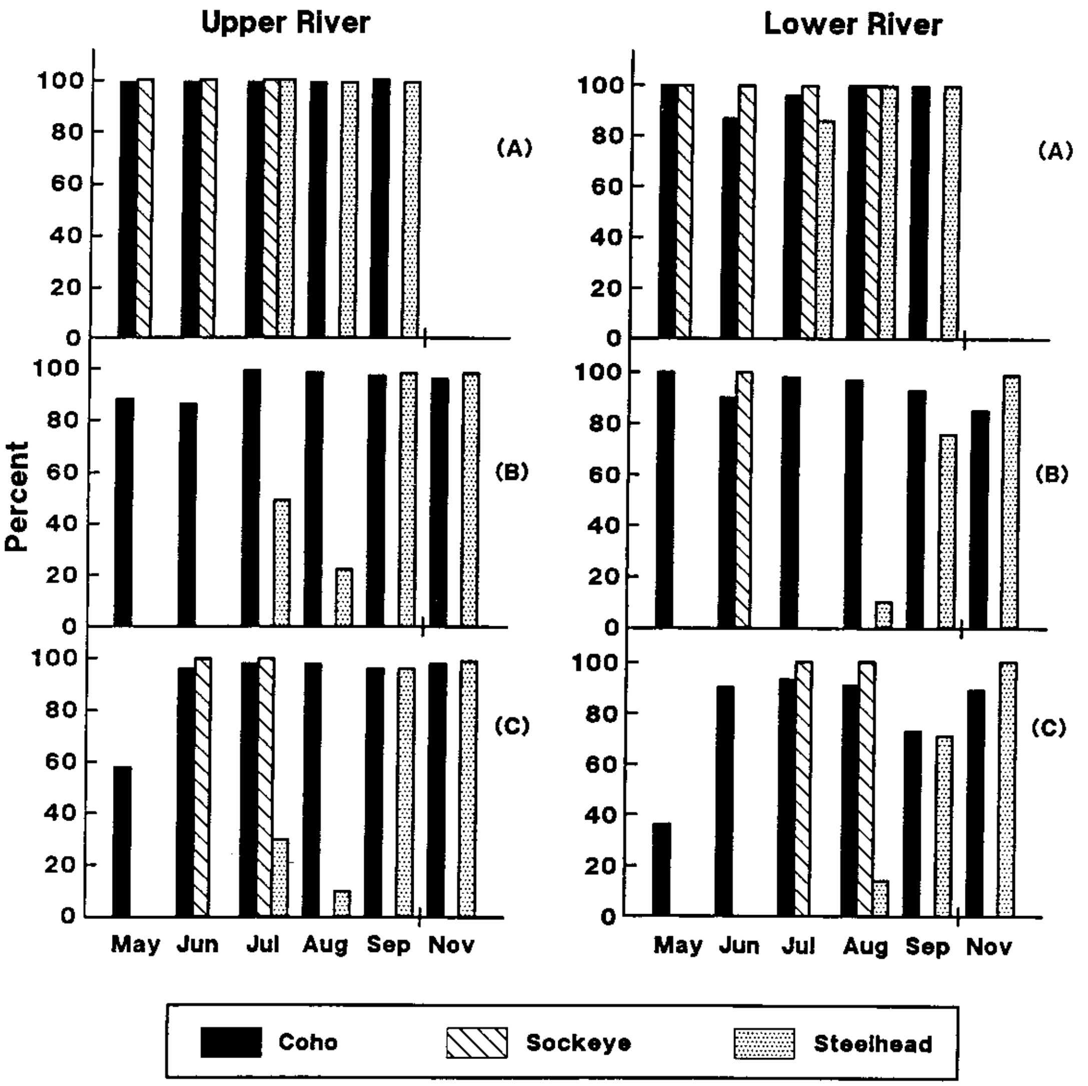

Figure 2. Percentage of fry (age 0) by habitat type in the upper and lower Situk River, Alaska, 1989. Dolly Varden fry are omitted because few were caught. (A = channel edges, B = willow edges, C = debris pools.)

155 steelhead, and 13 sockeye in the upper river and 471 coho, 17 steelhead, and 14 sockeye in the lower river. In November, coho and steelhead fry also were more abundant at the upper than at the lower river sites (Table 1).

## Parr Densities and Habitat Use

Coho, steelhead, and Dolly Varden parr densities (fish/100 $m^2$) differed significantly ($P < 0.05$) among habitat types at both the upper and the lower river sites. Parr densities were consistently greater in willow edges and debris pools than in channel edges (Figure 4). In the upper river, peak densities of coho (281, June), steelhead (82, August), and Dolly Varden (44, June) were in willow edges. In the lower river, peak densities of coho (36, July) and Dolly Varden (35, July) were in debris pools, whereas peak steelhead density (44, July) was in willow edges.

Within the same habitat types, mean density of coho and Dolly Varden parr was usually significantly ($P < 0.10$) greater at the upper than at the

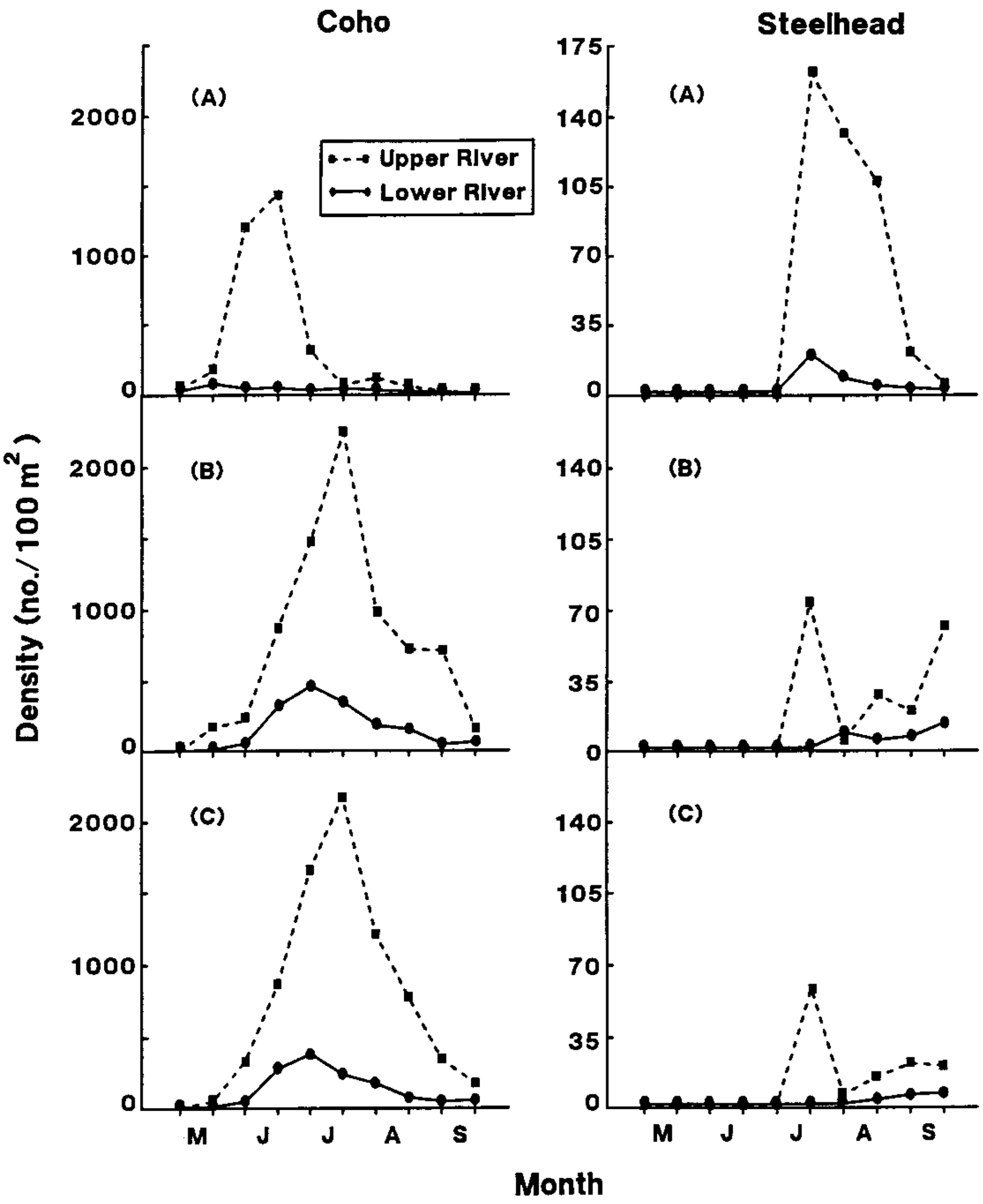

Figure 3. Mean density of coho salmon and steelhead fry (age 0) by habitat type in the upper and lower Situk River, Alaska. Sampling occurred biweekly from May through September 1989. (A = channel edges, B = willow edges, C = debris pools.)

lower river sites, whereas steelhead parr density was similar ($P > 0.10$) (Figure 4). Exceptions for coho and Dolly Varden were in channel edges and debris pools, respectively, where densities were similar ($P > 0.10$) between the upper and lower river sites. In November, 97% of all parr caught were in the upper river, and 93% were Dolly Varden (Table 1).

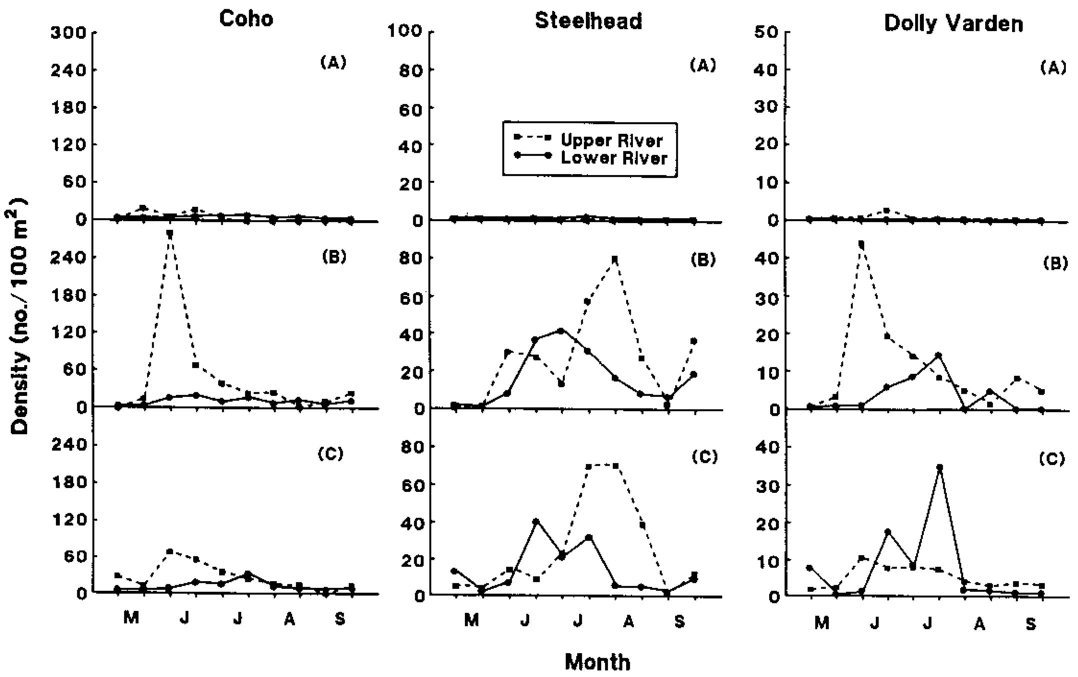

Figure 4. Mean density of coho salmon, steelhead, and Dolly Varden parr (age ≥ 1) by habitat type in the upper and lower Situk River, Alaska. Sampling occurred biweekly from May through September 1989. (A = channel edges, B = willow edges, C = debris pools.)

TABLE 1. Catch of juvenile salmonids in baited minnow traps set for 24 h at upper and lower Situk River sites on 30 November 1989. Two willow edges and two debris pools were sampled in each area of the river.

| | Number of fry (age 0) | | Number of parr (age ≥ 1) | | |
|---|---|---|---|---|---|
| | Coho salmon | Steelhead | Coho salmon | Steelhead | Dolly Varden |
| Lower river | | | | | |
| Willow edges | 78 | 123 | 0 | 1 | 1 |
| Debris pools | 63 | 54 | 0 | 0 | 0 |
| Total | 141 | 177 | 0 | 1 | 1 |
| Upper river | | | | | |
| Willow edges | 122 | 95 | 1 | 2 | 36 |
| Debris pools | 247 | 173 | 0 | 1 | 27 |
| Total | 369 | 268 | 1 | 3 | 63 |

## Fish Length

Length of fry of all species generally increased from May to September, but was similar in late September and November. Monthly mean fork length of fry (all habitat types in lower and upper river combined) increased from 36 to 64 mm for coho (May-November), 32 to 43 mm for sockeye (May-July), and 32 to 61 mm for steelhead (July-November). Fry of all species (all habitat types and sampling periods combined) were significantly ($P < 0.001$) larger at the lower than at the upper river sites (Table 2).

Length of parr of all species generally increased in most habitat types from May to August and declined thereafter. From May to August, monthly mean fork length (all habitat types in lower and upper river combined) increased from 60 to 86 mm for coho, 63 to 105 mm for steelhead, and

69 to 100 mm (May-July) for Dolly Varden. In September, monthly mean fork length was 83 mm for coho, 79 mm for steelhead, and 81 mm for Dolly Varden. Parr of all species (all habitat types and sampling periods combined) were significantly ($P < 0.001$) larger at the lower than at the upper river sites (Table 2).

TABLE 2. Fork length of juvenile coho and sockeye salmon, steelhead, and Dolly Varden (all sampling periods and habitat types combined) in the upper and lower Situk River, Alaska, May-November 1989. Data are means ± 1 standard error; sample sizes in parentheses.

| | | Fork length (mm)* | |
|---|---|---|---|
| Species | Stage | Upper river | Lower river |
| Coho salmon | fry | 48.4 ± 0.2<br>(5195) | 61.1 ± 0.2<br>(3178) |
| Coho salmon | parr | 73.2 ± 0.4<br>(1065) | 77.7 ± 0.4<br>(594) |
| Sockeye salmon | fry | 33.0 ± 0.3<br>(123) | 37.7 ± 0.7<br>(132) |
| Steelhead | fry | 43.9 ± 0.3<br>(1262) | 54.3 ± 0.9<br>(304) |
| Steelhead | parr | 90.3 ± 0.7<br>(911) | 98.3 ± 0.9<br>(677) |
| Dolly Varden | parr | 75.6 ± 0.8<br>(386) | 101.5 ± 1.6<br>(260) |

*All fork lengths were significantly ($P \leq 0.001$, t-tests) larger in lower river than in upper river.

## Discussion

Different habitat types in the main-stem Situk River provide important rearing habitat for different life-history stages of juvenile salmonids. Channel edges are important nursery areas for newly emerged fry, particularly coho in May, June, and July; sockeye in May and June; and steelhead in July and August. Coho, steelhead, and Dolly Varden parr primarily used willow edges and debris pools—areas with abundant cover. Results of trapping in late November suggest that coho and steelhead fry and Dolly Varden parr rear in willow edges and debris pools in late fall and probably in winter.

Few sockeye fry were caught in the Situk River after early July, and presumably most migrated to the estuary. Many sockeye fry in the main stem probably migrate to sea their first summer without spending a winter in fresh water (ocean type). Two separate emigrations of sockeye fry exist in the Situk River: an early emigration of newly emerged fry into the estuary in March and April and a later emigration of larger sockeye to the estuary in May and June (Thedinga *et al.* 1993). Most ocean-type sockeye probably originate from Old Situk River; scale analysis shows that 94% of the sockeye escapement to Old Situk River (about 3,000 sockeye) have no freshwater annulus (Alaska Department of Fish and Game 1990). Numbers of ocean-type sockeye peak in the Situk estuary in May and June, and most fish leave the estuary and go to sea by late July (Heifetz *et al.* 1989).

The greater densities of most species and life-history stages in the upper than in the lower river could be due to differences in habitat or food resources. Warmer water and abundant seston in outflow from Situk Lake could contribute to more suitable habitat and a more productive forage base in the upper main stem, thereby promoting greater densities of some species such as coho and Dolly Varden. Steelhead parr density, however, was similar in the upper and lower portions of the river, indicating that habitat and food resources that possibly promote greater densities of coho and Dolly Varden parr were not as important for steelhead. Availability of seston in the lake outlet drift could also benefit some species more than others. For example, in the lower Taku River, Alaska, at a site influenced by lake outlet flow, stomach contents of juvenile sockeye contained an abundance of crustacean zooplankton from the lake, whereas chinook and coho stomachs contained relatively few (Brownlee 1991). In addition, most coho and steelhead spawning is in the upper watershed (Thedinga *et al.* 1993); as they emerge and disperse, more fry might occupy habitat close to the spawning areas in the upper river than farther downstream. This could explain, for example, why peak coho fry density was at least three times greater at the upper than at the lower river sites.

Seasonal differences in parr density between the upper and lower sites of the Situk River probably reflect immigrations from wintering areas and subsequent emigrations to the ocean. Coho and Dolly Varden parr were most abundant in the upper river from late May to late June as they left wintering areas (e.g., Situk Lake) and moved into the main stem. Substantial numbers of coho, steelhead, and Dolly Varden parr reared in the lower river from late May to late July, but numbers had declined by early August, as some parr probably transformed to smolts and emigrated to sea. By late November any remaining parr had probably moved upstream to wintering areas. Some juvenile coho in Porcupine Creek, Alaska, emigrate upstream from the estuary to freshwater areas in fall (Murphy *et al.* 1984).

The larger size of juvenile salmonids in the lower than in the upper Situk River could be related to lower fish density. For most species, higher densities at the upper than at the lower river sites probably prevented faster growth. In laboratory studies with low- and high-density groups of coho and steelhead fry, the low-density group demonstrated greater growth (Fraser 1969). In addition, recruitment of emergent fry to upriver sites through summer probably resulted in lower mean sizes.

## Potential Impacts of Flooding

Flooding from Russell Lake could severely impact the Situk River from its confluence with Old Situk River downstream to the estuary (Figure 1). Average discharge could increase from 6 $m^3/s$ to about 220 $m^3/s$ during flooding, and exceed 1,100 $m^3/s$ during peak flows (Mayo 1988). The main stem could widen from 25 m (average) up to 2,500 m, and the "new" river will be cooler and turbid from glacial influence and increased sediment loads. The old-growth forest on the floodplain will probably be flooded, causing debris torrents.

Rearing habitat and food production will probably be altered by flooding. Willow edges and debris pools could be scoured, filled in, or washed away. Initially, food production will probably be depressed. Invertebrate populations in a Wisconsin stream remained low for 1 year after severe flooding (Elwood and Waters 1969). Habitats will probably be unstable for several years as the river channel adjusts to increased flow and to changes in sediment and debris loads.

Eventually the Situk River will stabilize as it forms a new channel. New willow-edge and debris-pool habitats will form in time. Loss of some main-stem rearing habitat could be partially offset by expanded rearing habitat in secondary floodplain channels and sloughs (Clark and Paustian 1989). The future Situk River could resemble the glacial Taku River near Juneau, Alaska. Peak flow of the Taku River in summer (>700 $m^3/s$; Murphy *et al.* 1989) is about the same as the predicted peak flow of the future Situk River. Although the main channel of the Taku River is too swift (1 m/s) for juvenile salmon, its channel edges, sloughs, backwaters, and wetlands provide important rearing habitat for juvenile chinook, sockeye, and coho (Murphy *et al.* 1989). More rearing habitat could become available with the creation of Russell Lake. Flooding could also redistribute fish into nearby rivers (Figure 1).

The cooler, turbid floodwaters of Russell Lake could affect the distribution and growth of some fish species in the Situk River. Studies of the glacial Taku River show that sockeye rear successfully in turbid waters (<350 NTU), whereas coho and steelhead avoid the turbid river and rear in clearwater tributaries or off-channel beaver ponds (Thedinga *et al.* 1988, Murphy *et al.* 1989). Coho, however, rear successfully in the less turbid (<100 NTU) Kenai River, Alaska (Bendock and Bingham 1988). Fish growth will probably be slower after flooding because of lower temperatures, reduced forage, and increased turbidity. In the lower Taku River, coho fry average 50 mm FL in September (Murphy *et al.* 1989) compared to nearly 65 mm FL in the lower Situk River.

The ocean-type life-history strategy of sockeye in the Situk River could disappear after flooding. Because of cooler water and slower growth, ocean-type sockeye that now rear in the flood zone (main stem and Old Situk River) for 3-4 months could remain in fresh water for a year or more before smolting. Longer freshwater residence could result in increased mortality. Conversely, ocean-type sockeye could survive and even flourish after the river stabilizes. In the glacial Taku River, ocean-type sockeye rear successfully in side sloughs and beaver ponds (Thedinga *et al.* 1988).

Flooding of the Situk River will be a natural catastrophe that will affect habitat and the distribution and growth of some fish species for many years. However, with information from this study, fisheries managers can identify strategies to restore juvenile fish and habitat that may be lost from the flooding. Thedinga *et al.* (1993) predicts that 2.8 million juvenile coho, 586,000 Dolly Varden, 85,000 sockeye, and 62,000 steelhead could be lost due to flooding. Some potential restoration strategies in the Yakutat area may include off-channel development of groundwater spawning channels, rearing ponds, and egg-incubation facilities.

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