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Seasonal Use of Small Tributary and Main-Stem Habitats by Juvenile Steelhead, Coho Salmon, and Dolly Varden in a Southeastern Alaska Drainage Basin

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Abstract.-The movement of juvenile salmonids between small tributaries and main-stem habitats in southeast Alaska watersheds is poorly understood. We observed movements of steelhead *Oncorhynchus mykiss*, coho salmon *O. kisutch*, and Dolly Varden *Salvelinus malma* between mainstem and tributary habitats at weirs located on tributaries in the Staney Creek watershed in southeast Alaska. We used seasonal relative abundance (catch per unit effort) in eight main-stem reaches and eight tributaries to corroborate observed movement in the two streams with weirs. We observed juvenile steelhead and coho salmon moving through the weirs into tributaries during the fall as flows increased and temperatures decreased. The relative abundance of steelhead was greater in main-stem sites than in tributaries during the summer, whereas during spring and fall relative abundance in the tributaries was similar to that in the main stem. Juvenile coho salmon were abundant in tributaries during all seasons. The relative abundance of Dolly Varden was greater in the tributaries than in the main-stem during all seasons. These results underscore the significance of links between main-stem habitats and small tributaries for production of juvenile salmonids.

Movements into off-channel refuge habitats by juvenile coho salmon *Oncorhynchus kisutch* in the fall and winter and emigration of coho salmon fry from spawning tributaries in spring or summer have been well documented, whereas seasonal movements between main-stem and tributary habitats by juvenile steelhead *O. mykiss* are less well known (Skeesick 1970; Bjornn 1971; Bustard and Narver 1975; Cederholm and Scarlett 1981; Peterson 1982; Tschaplinski and Hartman 1983; Swales et al. 1986; Hartman and Brown 1987; Brown and Hartman 1988; Nickleson et al. 1992). In Washington and Oregon, some presmolt steelhead move downstream out of natal tributaries into main-stem habitats to complete their freshwater residence (Everest 1973; Leider et al. 1986), and in Idaho, Bjornn (1971) described downstream movements of presmolt steelhead in fall, winter, and spring from a tributary of the Lemhi River. Cederholm and Scarlett (1981) observed fall immigration and spring emigration of juvenile steelhead into two small tributaries of the Clearwater River in Washington State. Seasonal movements of juvenile Dolly Varden *Salvelinus malma* between main-stem and tributary habitats also are not well known, but fall immigration into warmer spring-fed tributaries and spring out-migration of smolts from streams and lakes have been reported (Armstrong 1974; Armstrong and Morrow 1980).

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In southeast Alaska, juvenile coho salmon and Dolly Varden are found in tributaries and main-stem reaches throughout the year (Bryant 1984; Heifetz et al. 1986; Dolloff 1987), but little information on seasonal movements between main-stem and small tributary habitats is available. Dolloff (1987) observed little movement of transplanted juvenile coho salmon among stream reaches between surveys conducted in August, November, and the following April in a southeast Alaska stream. However, our observations of marked juvenile coho salmon indicate that a portion of the population enters beaver ponds and other off-channel habitats during the fall in southeast Alaska (M. D. Bryant, unpublished data).

Previous studies in southeast Alaska suggest that juvenile steelhead are absent or rare in small tributaries (Bryant 1984; Dolloff 1986; Bjornn et al. 1991). However, all of these studies were conducted during the summer months and therefore shed no light on whether juvenile steelhead utilize small tributaries during other seasons. Johnson et al. (1986) observed large variations in steelhead abundance between summer and winter samples in three southeast Alaska streams and attributed the differences to movement within the main stem, although they did not mark fish and did not sample small tributaries. Our objectives were to describe the magnitude and timing of juvenile salmonid movements between the main stem and small tributaries and to compare the seasonal relative abundance of juvenile salmonids in main stem and tributaries.

Methods

Study area.-Our study area was the Staney Creek watershed (drainage basin area = 164 km^2), located on Prince of Wales Island in southeast Alaska (Figure 1). The climate is cool and wet, with a mean annual temperature of about 7°C. Temperatures rarely exceed 20°C in the summer or fall below -10°C in the winter. Peak stream discharge, resulting from frequent rain events, occurs in October, with spates common in September and November; snowmelt causes spring high flows in April and May (Schmiege et al. 1974). Forested watersheds are composed primarily of Sitka spruce Picea sitchensis and western hemlock *Tsuga heterophylla* interspersed with Alaska yellow cedar *Chamaecyparis nootkatensis* and alder *Alnus* spp. on disturbed sites such as landslides, stream meanders, and logging roads (Harris et al. 1974). About 50% of the Staney Creek basin was clearcut, including large sections of riparian areas, beginning in the late 1960s. Logged areas are dominated by young-growth forest of Sitka spruce and western hemlock as well as salmonberry *Rubus spectabilis*, blueberries *Vaccinium* spp., and stink currant Ribes *bracteosum*.

Study design.-We used intensive and extensive study components to observe movements and seasonal use of main-stem and tributary habitats by juvenile salmonids. In the intensive component, we used weirs to monitor the timing and magnitude of juvenile salmonid immigration and emigration year-round at two second-order tributaries, Tye and Twiw Creeks (Figure 1). To complement the intensive component, we used seasonal relative abundance of juvenile salmonids in main-stem and small tributary habitats at 10 locations in the Staney Creek basin (including Tye and Twiw creeks) to corroborate seasonal movements observed at the two weirs.

The intensive component involved installing immigration/emigration weirs constructed from lumber and 6.4-mm-mesh plastic screening near the confluence of Tye and Twiw Creeks with Staney Creek. Upstream- and downstream-facing walls directed fish to separate holding pens. The weirs were designed to capture juvenile fish (>38 mm fork length [FL]). A two-step “fish ladder” was constructed that allowed adult coho and pink salmon *O. gorbuscha* to pass upstream around the weirs during high flows. The weirs were operated continuously from April 1996 through November 1997 and were checked daily during high-water periods (spring and fall) and at least every third day during low-water periods (summer and winter). Salmonids captured in the weirs were measured and weighed and all fish exceeding 50 mm FL were marked with a freeze-brand (Bryant et al. 1990). The freeze-brand identified the site (Tye or Twiw Creek), the direction of movement (upstream or downstream), and the time period when the fish was captured. Time periods were 15 or 30 d long except for the overwinter period, which lasted from 15 November to 1 April. Presmolts and smolts were distinguished on the basis of coloration; presmolt juveniles had cryptic coloration and visible parr marks, whereas smolts had silvery coloration and fin margin blackening (Wedemeyer et al. 1980). Water temperatures were monitored with submersible thermographs placed in Staney Creek near the confluences of Tye and Twiw creeks, and discharge data for Staney Creek were obtained from a U.S. Geological Survey (USGS) gauging station. Because the weirs were occasionally overtopped during freshets, which probably

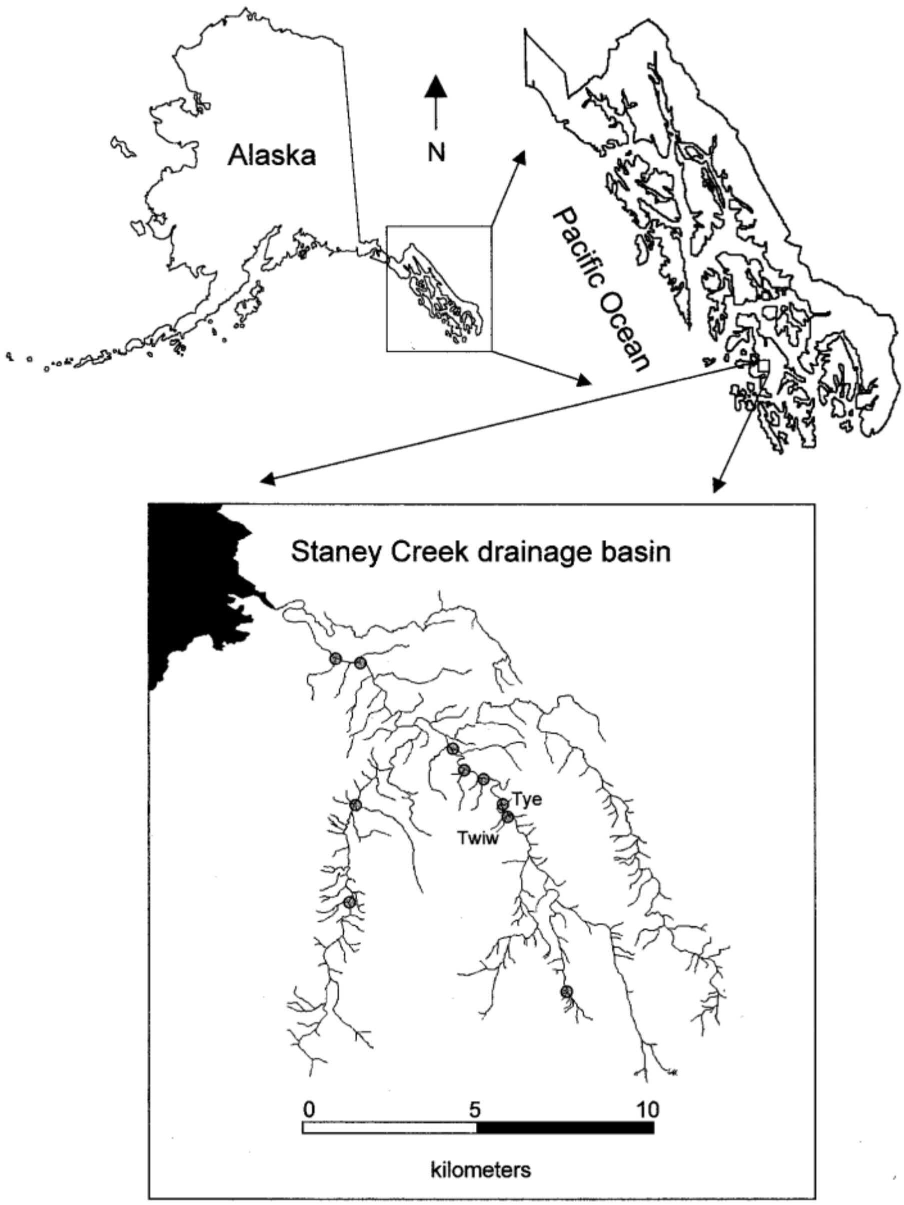

FIGURE 1.—Location of Staney Creek drainage basin, Prince of Wales Island, southeast Alaska. Dots show locations of study streams.

allowed some juvenile salmonids to avoid capture, the fish capture data serve as an index to fish movements rather than a census of all fish entering and leaving the creeks.

For the extensive component of the study, 10 paired locations (8 randomly selected sites, and Tye and Twiw creeks) were sampled in July and October of 1996 and in April, July, and October of 1997 (Figure 1). Each sampling location included a 200-m reach of a second-order tributary and a 200-m reach of Staney Creek or South Fork Staney Creek, centered at the confluence of the tributary. Sampling reaches in the tributaries began 100 m upstream from the confluence with Staney Creek, except at three sites that had beaver dams less than 300 m upstream from the confluence of Staney Creek. At these three sites, the tributary sampling area began closer to the Staney Creek confluence. Juvenile salmonids were captured with minnow traps (3.2-mm mesh, with 50-

mm openings at each end) baited with salmon eggs, a technique used in numerous studies in southeast Alaska (Bloom 1976; Elliott and Hubartt 1978; Bryant 1985, 2000; Dolloff 1986, 1987). Ten minnow traps were randomly placed in 20-m strata in each 200-m reach and left for at least 1 h when water temperatures were over 6°C. Minnow traps were set overnight (16-24 h) when water temperatures were less than 6°C. Ice cover on Staney Creek and tributaries prevented us from sampling with minnow traps during winter. No sites were located on the West or North Forks of Staney Creek, because steelhead were rare in the West Fork, and a waterfall about 0.6 km upstream of its confluence prevented access for anadromous fishes to most of the North Fork. Catch per unit effort (CPUE; fish/h) was calculated for steelhead, coho salmon, and Dolly Varden captured in minnow traps for each trapping, and CPUE in main-stem sites and in tributary sites within species and sampling occasion were compared by using the nonparametric Wilcoxon paired-sample test (Zar 1999). The second-order tributaries we sampled had mean bank-full widths ranging from 0.7 to 4.3 m and gradients ranging from 0.5% to 4.4%, and the adjacent main-stem reaches were third- or fourth-order streams with mean bank-full widths ranging from 4.2 to 37.2 m and gradients ranging from 0.6% to 1.5%.

Results

Steelhead

Juvenile steelhead migrated into Tye and Twiw creeks during fall and emigrated during spring (Figure 2). Although most juvenile steelhead captured at the weirs in fall were moving upstream, some were also captured moving downstream. For example, at Tye Creek in August through December 1996, 84% (N = 1,055) of steelhead captured at the weir were moving upstream, whereas in Twiw Creek, 75% (N = 379) of all juvenile steelhead were captured moving upstream. During the fall of both years, fewer steelhead entered Twiw Creek than entered Tye Creek.

Changes in relative abundance elsewhere in the watershed reflect movement of juvenile steelhead into tributaries during the fall. Mean steelhead CPUE in both summers was greater in mainstream habitats than in tributaries, and the difference was significant (Wilcoxon paired-sample test, $P = 0.01$) in summer of 1997 (Figure 3). In contrast, the mean CPUE for steelhead was not significantly different in mainstream and tributary habitats during the fall or spring (Wilcoxon paired-sample test, $P > 0.05$). The increase in the relative abundance of steelhead in the tributaries from summer to fall corroborates the movement into the tributaries that we observed at the weirs.

Peak immigration of juvenile steelhead into Tye and Twiw Creeks occurred in October during both 1996 and 1997, as water temperatures in Staney Creek cooled from 11°C to 4-5°C, with flows as low as 1.4 m^3/s punctuated with floods of as much as 45 m^3/s. More steelhead entered both creeks during fall 1996 than during fall 1997. For example, in September and October 1996, 834 juvenile steelhead were captured entering Tye Creek, but only 409 juvenile steelhead were captured entering Tye Creek during this period in 1997. However, this outcome may have reflected the more frequent freshets in 1997, when the weirs were overtopped, which probably allowed some fish to avoid capture. In October 1996, the Tye Creek weir was overtopped on 5 d, whereas in October 1997 the weirs were overtopped on 9 d.

Emigration from the two tributaries occurred primarily in April and May in 1996 and 1997 (Figure 2). Downstream movement was protracted, without pronounced pulses. Movement occurred as water temperatures gradually warmed from about 2°C to 9°C, accompanied by flows generally less than 2.8 m^3/s, with occasional rain-induced freshets to more than 28 m^3/s. Most emigrant steelhead we captured moving downstream in spring 1996 and 1997 were juveniles, but we also captured 31 steelhead smolts with FL ranging from 90 to 185 mm. Mean FL of steelhead smolts was 133 mm (SE = 5.11) for Tye Creek and 131 mm (SE = 4.96) for Twiw Creek. No steelhead fry or adults were observed at the weirs.

Coho Salmon

Seasonal movements of juvenile cqho salmon were similar to those of juvenile steelhead. Juvenile coho salmon entered the two tributaries during late summer and fall, primarily in September and October, and emigrated in April and May. A large immigration peak occurred in October 1996; no distinct peak was observed in 1997 (Figure 2). Juvenile coho were captured moving both upstream and downstream at weirs during fall 1996 and 1997. For example, in August through December 1996, 50% (N = 281) of juvenile coho salmon captured at the Tye Creek weir were captured going upstream, whereas during the same period in Twiw Creek, 70% (N = 852) of juvenile coho salmon captured at the weir were captured

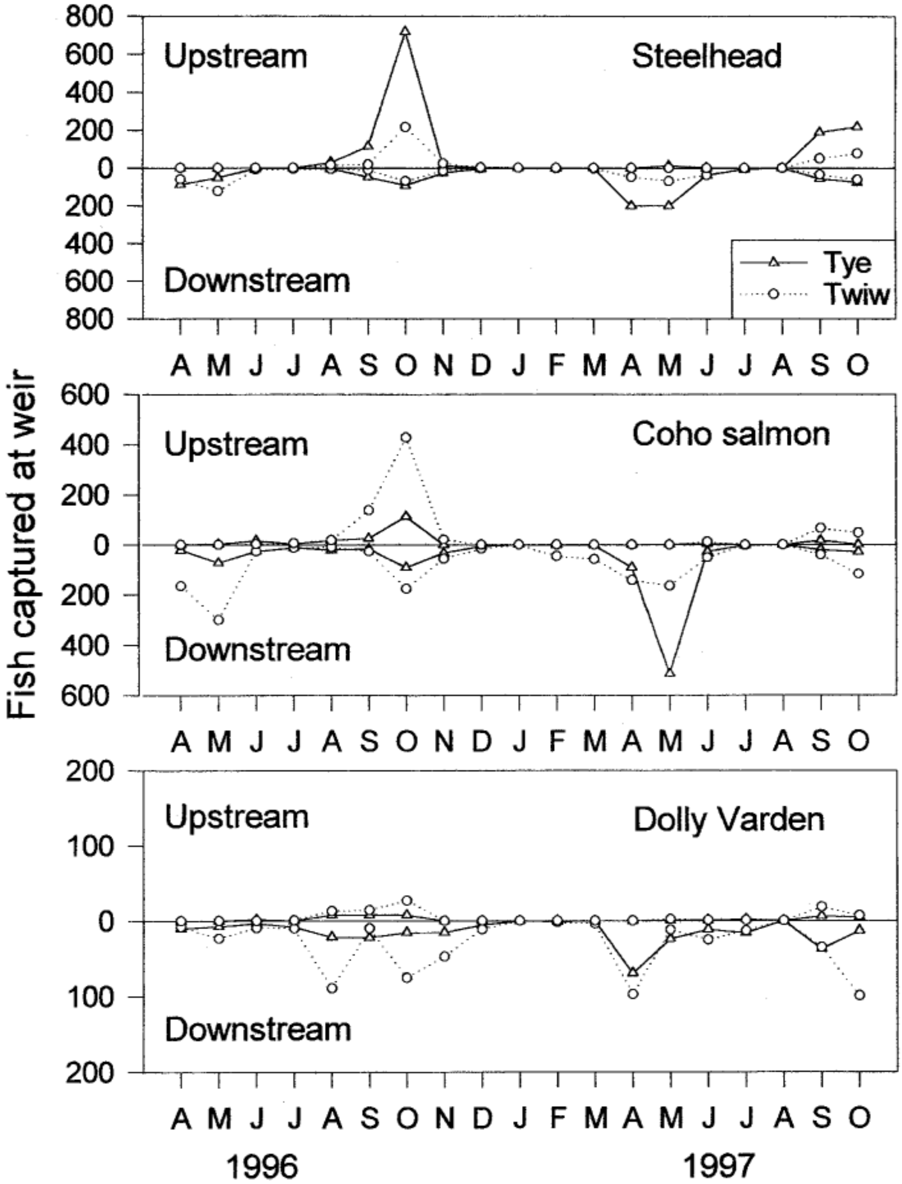

FIGURE 2.—Juvenile and smolt steelhead, coho salmon, and Dolly Varden captured at weirs on Tye and Twiw creeks (solid line is Tye Creek, dashed line is Twiw Creek), Staney Creek basin, Prince of Wales Island, southeast Alaska.

going upstream. In September and October 1997, more juvenile coho salmon were captured going downstream than going upstream in Tye and Twiw Creeks. Although we observed seasonal movement of juvenile coho salmon in both tributaries, the mean minnow trapping CPUE was not significantly different (Wilcoxon paired-sample test, $P > 0.05$) in mainstream sites and tributaries within season (Figure 3).

Coho salmon fry, smolts, and adults were observed at the weirs. Coho fry (<38 mm FL) were captured at both weirs during May and June in 1996 and 1997, but most fry were able to pass through the 6.4-mm mesh of the weir panels. We captured coho smolts ranging from 70 to 142 mm FL moving downstream at Tye ($N = 46$) and Twiw ($N = 127$) creeks from April to June in 1996 and 1997. Mean FL of coho salmon smolts was 91 mm

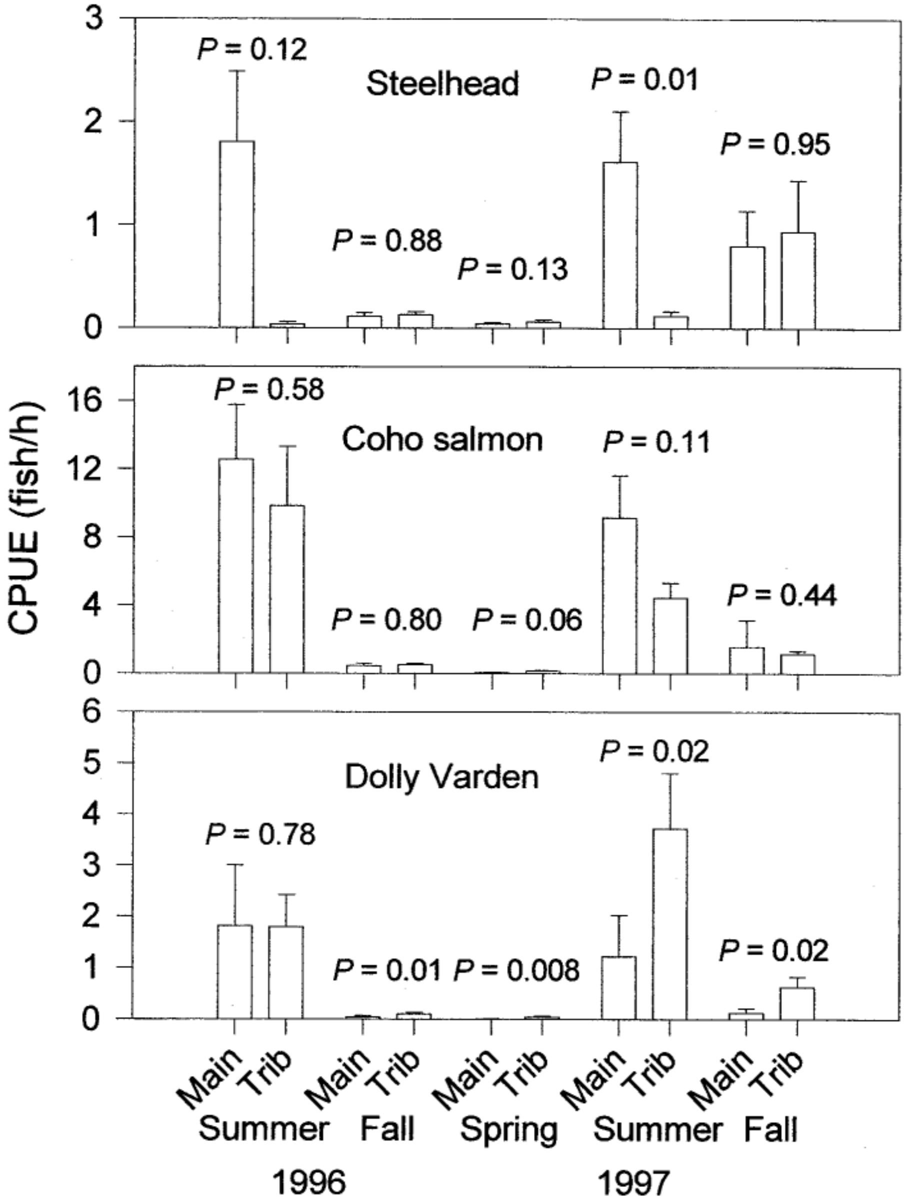

FIGURE 3.—Catch per unit effort for minnow traps in main-stem (Main) and tributary (Trib) sites during 1996–1997, Staney Creek basin, Prince of Wales Island, southeast Alaska. Error bars are 1 SE; *P*-values are the results of Wilcoxon paired-sample tests within species and season. Note the different scales on the y-axes.

(SE = 1.03) for Tye Creek and 89 mm (SE = 1.72) for Twiw Creek. We also captured 232 nonsmolt coho within this size range moving downstream during the same time period. Adult coho were observed entering and spawning in Tye and Twiw Creeks during fall 1996 and 1997.

Dolly Varden

The movements of Dolly Varden differed from those of juvenile steelhead and coho salmon. No distinct peaks of immigration by Dolly Varden into the tributaries were observed and more Dolly Varden were captured moving downstream (Tye Creek, N = 276; Twiw Creek, N = 566) than moving upstream (Tye Creek, N = 41; Twiw Creek, N = 83) (Figure 2). Juvenile Dolly Varden were captured moving downstream during nearly every month the weirs were operated, with peaks of emigration occurring in August, October, and November of 1996 and April, September, and October of 1997 (Figure 2).

Although more juvenile Dolly Varden moved downstream through the weirs, the mean CPUE of Dolly Varden was significantly higher (Wilcoxon paired-sample test, $P < 0.05$) in tributaries than in mainstream sites during all sampling occasions, with one exception. The mean CPUE for July 1996 was not significantly different in mainstream and tributary habitats (Figure 3).

We captured Dolly Varden smolts ranging from 90 to 165 mm FL moving downstream at Tye ($N = 30$) and Twiw ($N = 65$) creeks from April to June in 1996 and 1997. Mean FL of Dolly Varden smolts was 112 mm (SE = 1.90) for Tye Creek and 126 mm (SE = 1.79) for Twiw Creek. We also captured nonsmolt Dolly Varden within this size range at Tye Creek ($N = 11$ upstream; $N = 59$ downstream) and Twiw Creek ($N = 40$ upstream; $N = 305$ downstream). However, 314 of these larger out-migrants were captured from August through December, and only 49 were captured moving downstream from February through July. Adult Dolly Varden (either >200 mm FL or fish freely expressing milt) were captured moving upstream ($N = 11$) and downstream ($N = 62$) at both weirs, primarily during September and October. Adult Dolly Varden ranged up to 410 mm FL, and we captured males as small as 102 mm FL freely expressing milt.

Movement Behavior

Four movement patterns were apparent from recovery of branded fish at the weirs throughout the 2-year study: (1) temporary fall residence-emigrating juvenile steelhead, coho salmon, and Dolly Varden were captured with brands indicating that they had previously been captured entering the same creek. Multiple entries into Tye and Twiw creeks were also observed; steelhead, coho salmon, and Dolly Varden were occasionally recaptured with two brands, indicating previous capture within 60 d at the same location; (2) overwinteringall three species were captured emigrating in spring with brands indicating that they had previously been captured entering the same creek the previous fall; (3) spring to fall reentries-a very few coho salmon and Dolly Varden and no steelhead were captured entering a creek in fall bearing marks indicating capture the previous spring while emigrating from the same creek; and (4) between-creek residence-a very few steelhead were captured at the Twiw Creek weir with brands indicating previous capture at the Tye Creek weir.

Discussion

Seasonal use of small tributaries by juvenile salmonids has not been well documented in southeast Alaska. We observed fall migrations into and overwintering in small tributaries by juvenile steelhead and coho salmon. These observations were similar to those reported for juvenile steelhead (Cederholm and Scarlett 1981) and coho salmon (Skeesick 1970; Bustard and Narver 1975; Cederholm and Scarlett 1981; Peterson 1982; Brown and Hartman 1988; Nickleson et al. 1992) elsewhere in the Pacific Northwest.

The pattern of immigration and emigration for Dolly Varden at the tributaries differed from that of steelhead and coho salmon. Because we captured many more Dolly Varden moving downstream than upstream at both weirs, adults as large as 410 mm FL at the weirs in fall, and smolts emigrating from Tye and Twiw Creeks in spring, clearly the anadromous Dolly Varden used the tributaries for spawning and rearing habitat. Armstrong and Morrow (1980) also reported on the use of tributaries for spawning and rearing by anadromous Dolly Varden. However, because we also captured mature male Dolly Varden as small as 102 mm FL, we suspect that tributaries also provide habitats for the stream resident form (Armstrong and Morrow 1980). The presence of both resident and anadromous forms of Dolly Varden may account for the net downstream movement and the complex movement pattern between tributaries and main-stem habitats that we observed.

In addition to their overwintering in tributaries, we observed that some juvenile steelhead and coho salmon occupied tributaries temporarily during fall, perhaps using them as refugia during rain-induced freshets. We also documented that some individual fish had short periods of residence in both Tye and Twiw creeks and that some fish reentered the same creek in consecutive falls. We do not present a quantitative analysis of brand recoveries because, as a result of flooding, the weirs may not provide an unbiased estimate of the ratio of marked and unmarked fish. Temporary occupation of off-channel riverine ponds during fall freshets by juvenile steelhead was also reported by Cederholm and Scarlett (1981). Because the largest predictable rainfall events and streamflows in Staney Creek occur in fall and early winter (USGS streamfiow data; water years 1964-1981 and 1989-1997), juvenile steelhead and coho salmon may have evolved the behavior of moving into small tributaries as an adaptation to avoid unfavorable main-stem conditions during fall floods. Overwintering conditions may also be more favorable in tributaries; we observed that ice cover was more stable in Tye and Twiw Creeks than in Staney Creek, where thaws and freshets caused ice breakups and jams.

In spring, moderate numbers of steelhead, coho salmon, and Dolly Varden smolts emigrated from the tributaries, demonstrating that some smoltification occurs while fish are still in tributaries. However, because many nonsmolts larger than the smallest smolts were also captured emigrating, probably not all smoltification takes place within tributaries, as has been previously observed for steelhead (Leider et al. 1986; Loch et al. 1986), coho salmon (Cederholm and Scarlett 1981), and Dolly Varden (Armstrong and Morrow 1980).

Our results from minnow trapping at other sites in the Staney Creek basin supported our observations at the weirs, indicating that juvenile steelhead largely abandon small tributaries during summer, whereas during April and October they are found in both small tributary and main-stem habitats. In contrast, small tributaries provide year-round habitat for Dolly Varden and juvenile coho salmon.

Attributing exogenous triggering factors to fish movement in uncontrolled natural environments is difficult and largely speculative. However, because the fall movements we observed with weirs at two tributaries were synchronous for juvenile steelhead and coho salmon, fish may be responding to environmental cues such as decreasing water temperature, flow regimes, or photoperiod. Although we did not investigate statistical relationships of movement to any of these factors, fall movement coincided with declining water temperatures and the rain-induced freshets common during October in southeast Alaska. Juvenile salmonids have been observed entering tributaries and off-channel habitats from main stem during fall freshets in Oregon (Skeesick 1970), Washington (Cederholm and Scarlett 1981), and British Columbia (Tschaplinski and Hartman 1983).

Conclusions and Management Implications

In the southeast Alaska drainage basin we studied, juvenile steelhead and coho salmon had conspicuous movements between main-stem and small tributary habitats. Juvenile steelhead and coho salmon entered tributaries during the fall freshets as water temperature declined and then moved out of tributaries in spring. Little movement between the main stem and tributaries of either juvenile steelhead or coho salmon was observed during winter and summer. Many juvenile coho salmon remained in tributaries throughout the summer, but steelhead were rare in tributaries in summer. Dolly Varden were more common in tributaries than in main-stem habitats throughout the year, and both resident and anadromous Dolly Varden used small tributaries.

These results underscore some important considerations for managing watersheds that support anadromous salmonids in southeast Alaska. Links between main-stem and small tributary habitats are important to juvenile fish as well as returning adult fish. For example, coho salmon and Dolly Varden spawn, rear, and overwinter in the small, secondorder tributaries, and juvenile steelhead overwinter there. Most surveys of fish populations occur during the summer, when steelhead are largely absent from tributaries. Although the presence of other anadromous species may mandate a high level of riparian protection for the stream, summer fish surveys will not provide a complete picture of the watershed and its potential to support other species. In many locations, steelhead are more sensitive to perturbations than juvenile coho salmon and are more likely to be identified as a sensitive species. Watershed surveys that overlook the significance of seasonal shifts in habitat use, particularly in tributaries, will provide an incomplete representation of the habitat requirements for all species.

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