Residence Time, Habitat Utilization and Growth of Juvenile Coho Salmon (*Oncorhynchus kisutch*) in South Slough, Coos Bay, Oregon

Preliminary Report of Findings
November, 2000

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Bruce A. Miller and Steve Sadro

Abstract

The juvenile life history of coho salmon was investigated over a 16-month period in the upper estuarine portion of Winchester Creek, the principal tributary of South Slough, Coos Bay, Oregon. Dye-marked coho were resident in the uppermost reaches of South Slough for at least four months and utilized the tidal channel, recently restored salt marshes, and off-channel beaver ponds. Age-0 coho were present for at least three months and individually marked fish were resident for at least 52 days. We estimated a total of 5547 migrants for the 1998 brood year. At least three different life-history types were identified: 13.2% of migrants entered the estuary in the spring as age-0 fry, 34.1% entered tidewater in the fall and winter as pre-smolts, and 53.7% migrated to the estuary in the spring as age-1 smolts. Dye-marked coho recaptured in the tidal channel indicated 50% of migrants spent up to 23 days in upper estuarine and associated habitats, 25% resided from 24 to 43 days, and 25% resided from 44 to at least 114 days. There was also a seasonal component to residence time. Longest residence times were accrued by age-0 spring migrants and age-1 fall and winter migrants, while age-1 spring migrants tended to reside less than one month. The fate of the age-0 spring migrants is not completely known, but some portion may have re-ascended into the uppermost reaches of tidewater as summer water temperatures and salinities increased. Juvenile coho found in the upper estuarine portion of Winchester Creek in the fall utilized very productive habitats before emigration from the system as smolts in winter or spring. A non-normal distribution in fork length of fish sampled in the upper estuary during the fall suggests fish originated from more than one population; some fish most likely resided over summer in upper tidewater while others moved downstream from the upper watershed. Populations of age-0 fry in upper estuarine habitats had growth rates as high as 0.44mm day^{-1}, almost double the 0.25mm day^{-1} for fish sampled in the upper watershed during the same period. Fish that reared in a beaver pond near head of tide had growth rates of 0.30mm day^{-1}. Fish that foraged in a restored salt marsh for only a few hours at high tide had higher condition factor than fish sampled in the adjacent tidal channel, indicating better forage opportunities in fringing marsh.

Introduction

Monitoring of life-history of juvenile coho salmon in South Slough began as part of a comprehensive program by South Slough National Estuarine Research Reserve (SSNERR) to restore formerly diked marshes and measure the effects of restoration on biotic communities within the reserve. In 1999, enumeration of out-migrating juvenile salmonids and returning adult spawners in Winchester Creek was begun by the Oregon Department of Fish and Wildlife (ODFW) as part of a broader effort coordinated under the Oregon Plan for Salmon and Watersheds (OPSW). This report is a preliminary summary of those monitoring activities conducted jointly by SSNERR and ODFW for the period spring 1999 through spring 2000.

Within the Pacific Northwest, most juvenile salmonids (*Oncorhynchus* spp.) utilize estuarine habitats (tidal channels and adjacent mud flats and salt marshes) during their migration to the ocean. Estuaries provide a spatial salinity gradient that facilitates physiological adaptation

from fresh to salt water habitat, and they provide a rich foraging environment (Healey 1982; Iwata and Komatsu 1984). Faster growth during the period of estuarine residence has been shown to increase subsequent marine survival (Reimers 1973; Macdonald et al. 1988; Levings et al. 1989; Solazzi et al. 1991; Northcote 1997; Pearcy 1997; Trotter 1997). Increased growth rates during estuarine residency have been correlated with high levels of productivity from associated saltmarsh and wetland habitats, thereby linking wetland productivity to early marine survival (Parker 1962, 1968; Peterman 1978).

Until recently, the use of estuaries by juvenile salmonids received little attention from an estuarine resource management perspective. However, the vast historical loss and alteration of wetland habitats has likely affected the function of most estuarine environments as temporary residence areas for juvenile salmonids (Simenstad et al. 1982). While 42% of coastal wetlands in the Pacific Northwest have been lost (Boule and Bierly 1986; Simenstad and Thom 1992), the Coos Bay watershed alone has lost over 86% of its original wetlands (Hoffnagle and Olson 1974). These alterations to natural estuarine habitats have resulted in changes to the dynamics of estuarine food webs and a reduction in available rearing habitat, which in turn may influence the migratory behavior, residence times, and growth rates of fish that enter the estuary. The destruction of coastal wetlands due to agricultural and industrial development, pollution, and other human activities is a major threat to the future of some salmon populations (Thayer 1992). Consequently, estuarine habitat protection and restoration are increasingly viewed as important in aiding the recovery of depleted anadromous fish populations.

Juvenile life history varies between species of salmonids and may vary geographically within species. This variation in life history is reflected in the different age of out-migrants, season of migration, and variable residence times within estuarine habitats. Juvenile chinook typically migrate as sub-yearlings during summer and fall and may spend up to several months in the estuary (Reimers 1973; Nicholas and Hankin 1988; Healey 1991). Juvenile chum also migrate as sub-yearlings during spring but display relatively rapid movement through the estuary (Mason 1974; Myers and Horton 1982; Iwata and Komatsu 1984; Salo 1991). Life history studies of coho suggest that in most systems, juveniles remain in freshwater in the upper watershed for one year, then migrate to the estuary during spring as yearlings (Reimers 1971; Durkin, 1982; Healey 1982; Myers and Horton 1982; McMahon and Hartman 1987; Moser et al 1991; Sandercock 1991; McMahon and Holtby 1992).

Migratory behavior of juvenile coho has been studied primarily by sampling during spring and summer months, which allows enumeration of age-0 fry and age-1+ juveniles. The migration of age-0 fry into the estuary has long been documented (Salo and Bayliff 1958) and has been attributed to both density dependant (Chapman et al 1961; Chapman 1962) and density independent (Tschaplinski 1988) causes. Few studies have monitored migrants during fall and winter months when high stream flows make operation of migrant traps difficult or inefficient. There is evidence, however, that in some systems a portion of sub-yearling coho migrate downstream during fall and winter (Rodgers, et al 1987). The fate of sub-yearling coho migrants is still not clear, but a portion of these early migrants may move to upper estuarine habitats and rear for some period prior to out-migration as smolts.

The residence time of juvenile coho in estuarine habitats is not well documented and where reported is usually limited to ranges of possible residence time (Myers and Horton 1982; Tschaplinski 1988) or time spent in specific marshes or sloughs (Shreffler et al 1990; Miller and Simenstad 1997). They are generally described as being present in the estuary for up to three months in the spring with early migrants residing longer than later migrants.

There is still little information on the variability of juvenile life histories of coho between systems. Further, in those systems where estuaries may provide an important role in juvenile life history, little is known regarding relative proportions of sub-yearling and yearling migrants, types of estuarine habitats utilized, and residence times within specific habitats. In 1998, we

began a study to determine the juvenile life history of a coastal population of coho in Oregon and how juveniles may utilize a variety of habitats associated with the upper estuary.

On the southern Oregon coast, South Slough forms a 19,300 acre sub-basin of the Coos Bay estuary, with Winchester Creek as the principal tributary. Most of the estuarine portion of South Slough is managed by SSNERR, while the upper watershed is owned by Coos County and private timber companies and is managed for timber production. Salmonids that use tributaries of South Slough for spawning and rearing include coho salmon, coastal cutthroat trout, and to a small degree, steelhead trout.

Methods

History of South Slough

Alteration of estuarine habitat in South Slough began in the early 1900's when the Winchester Creek channel was dredged and fringing marshes diked to facilitate access for upland timber harvesting. Diked tidelands were subsequently drained and maintained for agricultural use. Original drainage channels were filled and new channels were constructed along the periphery of the former marshes. Tidegates were used to prevent influx of tidal flow while facilitating freshwater drainage. This transformation resulted in a large loss of complexity and diversity in channel and marsh structure in the upper estuary and greatly affected habitat available to fish and estuarine prey organisms. By the late 1960's, diminished agricultural activities in South Slough left much of the converted marsh lands fallow, and failed tidegates allowed limited incursion of tidal flow into some diked areas. These areas were characterized by limited tidal exchange, artificial drainage ditches, and plant communities comprised of non-native pasture grasses and native salt marsh vegetation (Cornu 1997).

The upper portion of South Slough was designated as part of the South Slough National Estuarine Research Reserve in 1974. Between 1996 and 1998 the Winchester Tidelands Restoration Project was implemented to restore tidal wetland function to altered marsh areas within the reserve. This project, supported by the Coastal Wetland Conservation Grant Program of the US Fish and Wildlife Service, resulted in the removal of earthen dikes from five sites including Cox, Dalton and Kunz marshes and re-conversion of artificial drainage ditches to meandering tidal channels through marshes with freshwater input.

Study Area

The upper reaches of Winchester Creek are terrace constrained and have an average gradient that ranges from < 1.0% in the lower portions to 3.7% in the uppermost portion. Spawning habitat for coho salmon is currently limited to one of three principal forks. Timber harvest activities have probably impacted spawning habitat in the two other forks. The lower reach is very low gradient and the channel is unconstrained within an active flood plain in a broad valley. Substrate is predominantly silt and sand in the lower reaches. Beaver ponds are common throughout the entire watershed. Mean monthly discharge of Winchester Creek ranges from < 2 cfs during summer to > 200 cfs during winter and temperatures range from 6° to 16° seasonally.

The upper estuarine reach of Winchester Creek may be divided into two distinct habitat types. The upper portion (Reach A) extends from the head of tidal influence to approximately 1 km downstream and is characterized by a narrow, deeply entrenched stream channel with embedded large woody debris (Figure 1). Riparian vegetation consists primarily of dense fresh-water marsh grass (*Carex obnupta*) and occasional sitka spruce. Tidal range is 0 to

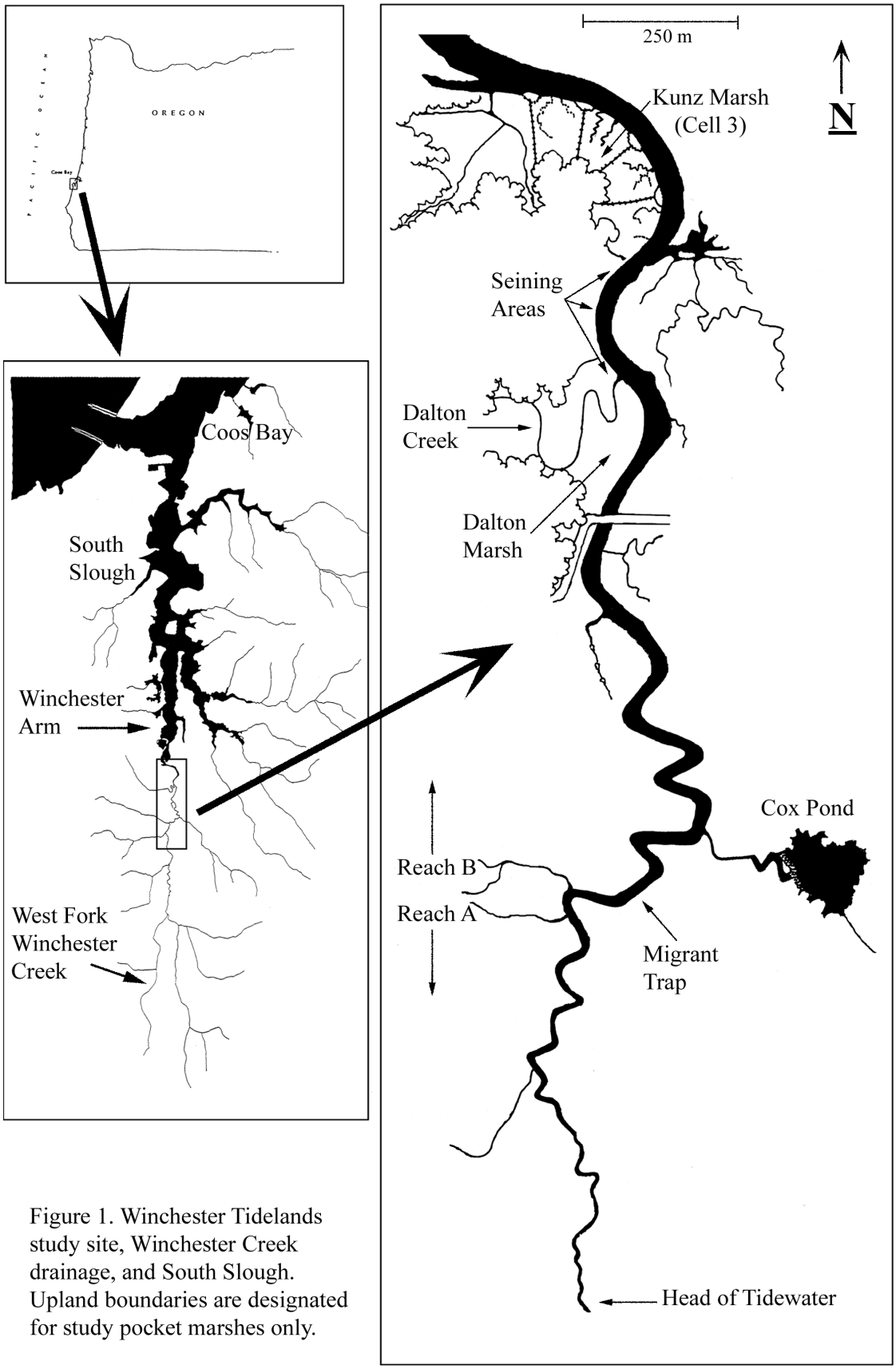

Figure 1. Winchester Tidelands study site, Winchester Creek drainage, and South Slough. Upland boundaries are designated for study pocket marshes only.

approximately 1 m, and salinity at high tide ranges from 0 during high winter flows to ~ 10 ppt during low summer flows. Temperatures range from 6° to 16° in the uppermost portion of this reach and to 20° in the lower portion.

In the second habitat type (Reach B), Winchester Creek broadens to tidal mudflats and fringing salt-marsh. Tidal range is up to approximately 3 m, salinity ranges from close to 0 ppt during high winter stream flows to ~ 32 ppt during lower summer flows, and temperatures range from 6° to 22° seasonally.

Location of sampling sites is shown in Figure 1. Kunz and Dalton marshes are restored tidal wetlands that have been reconnected to the tidal channel by removal of dikes and tide gates. The tidal channel in Dalton Marsh has also been reconstructed to facilitate drainage of Dalton Creek through the marsh. There is no spawning habitat in Dalton Creek. Fish were also sampled in the tidal channel of Winchester Creek adjacent to Dalton Marsh. An additional sample site associated within this reach is Cox Pond, a large beaver pond (approximately 5600 m^2) connected to the tidal channel by Cox Canyon Creek. There is no spawning habitat in this tributary to Winchester Creek.

Number and Timing of Out-Migrants

The West Fork of Winchester Creek, 5.5 km above the migrant trap, was sampled by electro-fishing at one-month intervals from April 1999 to May 2000 to measure growth of juvenile coho residing in the upper watershed.

The downstream migration of juvenile coho in Winchester Creek was monitored daily using a 1.53 m diameter rotary screw trap. The migrant trap was located approximately 1 km below head of tidal influence and at the transition point between Reach A and Reach B. Because the trap site was under tidal influence, the trap drum turned only during ebb and low tide, an average of 11.9 hours per day. During very low flows in late spring 2000, the drum on the screw trap was powered with a 12-volt motor that was controlled with a float switch and photovoltaic switch to operate only during night-time ebbing and low tide. The trap was operated from February 5 to May 23, 1999, and from November 9, 1999 to June 1, 2000.

Trap efficiency was determined by releasing a sample of marked fish above the trap and determining rate of recapture. A caudal fin-clip or dye mark was applied to all fish caught. Newly caught fish were marked and released 100 m upstream of the trap using an automatic mechanism that released fish at dusk (Miller et al., 2000) while recaptured fish were released 100 m downstream of the trap. Total number of migrants each week (N_T) was calculated using the formula:

N_T = total catch / trap efficiency.

All coho caught between February 9 and March 18, 1999, were given a caudal fin clip and released above the trap to determine trap efficiency. We initially assumed that fish migrated past the trap site only once and that only fish released above the trap would have any chance of being caught again. To test this assumption, we applied unique dye-marks to all fish captured after March 18 (see *Residence Time of Dye-marked Recaptures*, below, for marking methods).

Preliminary results of dye-marking in spring 1999 indicated that some portion of fish that migrated past the trap subsequently swam back upstream, which increased the probability of capturing an individual fish. Assuming marked and unmarked fish moved above the trap at the same rate, this behavior would not affect measured trap efficiency, but would affect total catch. During weeks when marked fish were recaptured more than once, the weekly estimate of migrants (N_e) was calculated by adjusting total catch using the formula:

$N_e = C_a / E$

where:
Ca = (total catch * number fish recaptured once) / total recaptures
E = number fish recaptured once / total marked

Residence Time of Dye-marked Recaptures

All fish were dye-marked on the ventral surface from just anterior to the pectoral fins to just posterior of the ventral fins. Recaptured fish were also given a unique mark each time they were recaptured. From March 19 to May 23, 1999, fish were dye-marked with a subcutaneous injection of black India ink using a syringe. During this period, marks were changed at one-week intervals. Beginning fall 1999, all fish were dye-marked using a needle-less dental injector with either alcian blue (a copper phthalocyanine derivative) at a concentration of 6.4×10^{-2}g/ml water, or India ink (Arnold 1966; Hart & Pitcher 1969). During this period, new marks were applied at three-day intervals, permitting finer resolution of residence time for fish subsequently recaptured. The number of days since initial capture for fish subsequently recaptured was calculated from the mid-point of the three day period assigned to each dye-mark.

In order to locate as many marked coho as possible and determine residence times in other habitats, sampling occurred at several other sites within the upper estuary (refer to Figure 1):

1) Cox Pond (315m downstream of the migrant trap) was sampled at one-month intervals from November 1999 to May 2000. Fish were given a unique dye-mark with a subcutaneous injection of Alcian Blue.
2) Dalton Marsh, 1.4 km below the migrant trap, age-0 fry that migrated into Dalton Creek from tidewater were sampled with a short seine at one to two week intervals during spring 1999. All fish captured were marked with a caudal fin clip.
3) In the tidal channel 1.5 km downstream of the migrant trap, a 25 m beach seine was used to sample fish at one to four week intervals. Fish were given a unique dye-mark with a subcutaneous injection of India Ink.
4) Kunz Marsh (Cell 3), 1.8 km below the migrant trap, fish that migrated from the adjacent tidal channel and utilized the marsh during high tide were sampled at monthly or more frequent intervals. Fish were sampled by placing the bag of a modified 50 m seine over the principal drainage channel in one of four experimentally restored cells of Kunz Marsh at high spring tide. Fish became trapped in the bag as water drained from the marsh during ebb flow. During the period November 1998 to April 1999, fish were sampled at one-month intervals during daytime spring tides. Beginning April 2000, Kunz marsh was sampled at two to four week intervals during the nighttime spring tides. Fish were given a unique dye-mark with a subcutaneous injection of India Ink.

A population estimate of juvenile coho resident in Cox Pond during winter 2000 was made using a modified Peterson mark-recapture methodology:

$$N = ((M + 1)(C + 1)) / (R + 1)$$

where:

M = Number of juvenile coho dye-marked on 12/17/99
C = Number of juvenile coho observed for dye-marks on 12/30/99
R = Number of recaptured dye-marked fish observed on 12/30/99

Size, Growth and Condition Factor of Migrants and Recaptured Fish

Fork length of all juvenile coho caught was recorded. Beginning February 2000, wet weight was measured to the nearest 0.1g using an Ohaus "Scout" balance, and condition factor was calculated from length and weight data using the formula:

$$KFL = (\text{weight} \times \text{length}^{-3}) \times 10^5$$

Growth rates of juvenile coho in upper estuarine habitats were determined from recaptured dye-marked fish by calculating a linear regression between fork length and number of days since initial capture. Growth rates of coho caught in West Fork Winchester Creek were calculated for specific time periods by taking the difference in mean fork length of the population and dividing by the number of days between sampling events.

Results

Number and Timing of Out-Migrants

Table 1 summarizes number of juvenile coho that migrated from Winchester Creek during the period spring 1999 through spring 2000. Trap efficiency was 0.10 in spring 1999 but increased to 0.17 for the period fall 1999 through spring 2000 following installation of weir panels at the migrant trap.

Table 1. Estimated number of coho out-migrants in Winchester Creek, by brood year and sample period. The fall/winter period was defined as November through February.

Brood Year	Sample Period	Estimated Migrants
1997	Feb. 5 – May 23, 1999	2247 (age-1 only)
1998	Feb. 5 – May 23, 1999	680 (age-0)
	Nov. 9, 1999 – Feb. 27, 2000	1890 (age-0+)
	Feb. 27 – June 1, 2000	2977 (age 1)
1999	Prior to Mar. 22, 2000	745 (age-0)
	Mar. 22 – June 1, 2000	123 (age-0)

Age-1 smolts of the 1997 brood first appeared at the migrant trap in February with a peak in migration in late April and early May, 1999 (Figure 2).

A portion of the 1998 brood of juvenile coho migrated to tidewater as age-0 fry, with a peak in migration in late March and early April, 1999. The 1999 brood also displayed a spring migration of age-0 fry to tidewater.

Juvenile coho were caught immediately after the migrant trap was installed in fall 1999. Trapping commenced after the first freshet and subsequent increase in stream flow, thus it is likely that some portion of fall migrants were missed. Juvenile coho continued to move into tidewater through the fall and winter, then displayed a sharp increase in migration at the end of February, with a peak in spring migration in early April.

Both the 1997 and 1998 brood showed a pattern of low numbers of age-1 migrants in winter followed by a sharp increase during spring (Figure 2). This temporal pattern of migration was used to apportion total migrants for the 1998 brood year by period of migration. Age-0 fry (spring migrants) comprised 13.2% of total migrants. The point of deflection at the end of February between relatively low numbers of winter migrants and the sharp increase in spring migrants was used to define combined fall and winter migrants (34.1% of total) and age-1 spring migrants (53.7% of total).

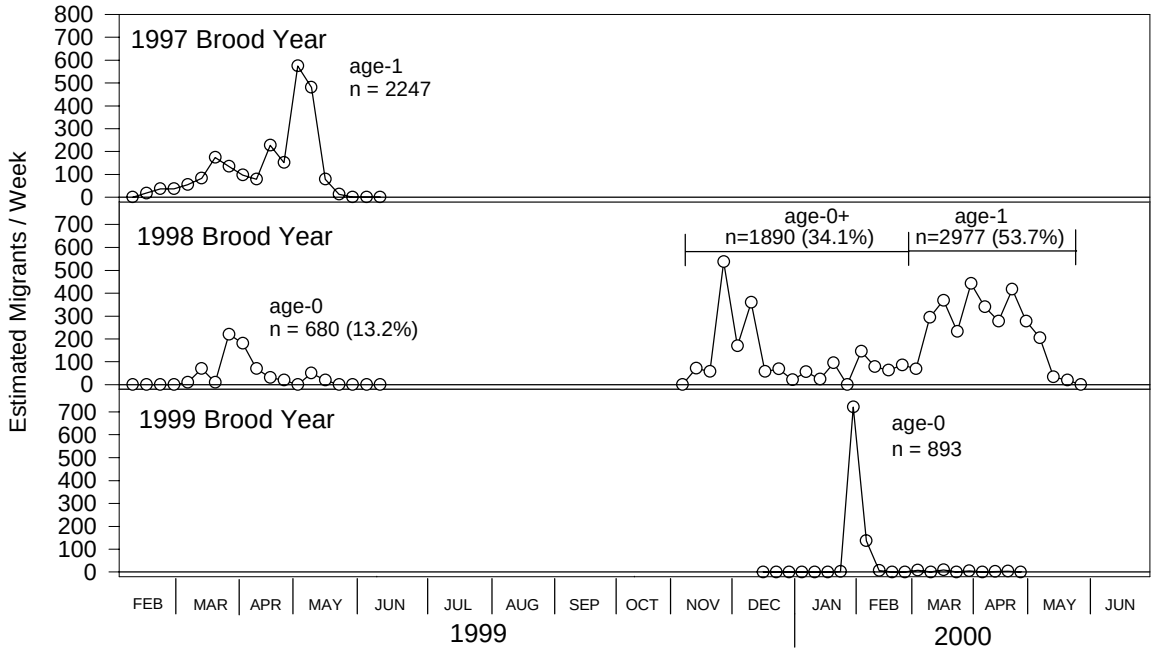

Figure 2. Estimated number and timing of outmigrating juvenile coho for the 1997 brood year (age-1 only), 1998 brood year, and 1999 brood year (age-0 only) in Winchester Creek, Coos Bay, Oregon.

Residence Time of Dye-marked Recaptures

In spring 1999, most dye-marked fish that were released above the trap were recaptured at the trap within several days of release. However, some fish were recaptured as many as 20 to 50 days later, suggesting either delayed downstream migration or upstream migration of some portion of migrants that had moved past the trap. Recapture of three fish at the migrant trap that were marked in the tidal channel near Dalton Marsh suggested some portion of migrants (5.3%) did re-ascend Winchester Creek.

Beginning fall 1999, most marked fish released above the migrant trap were recaptured within two days of release, but a substantial number were recaptured as much as 128 days later (Figure 3). Six fish (3.7% of recaptures) were recaptured at the trap twice, and three fish (1.8% of recaptures) were recaptured three times. Four of the fish recaptured at the migrant trap (2.4%) were originally marked in the tidal channel near Dalton Marsh and subsequently re-ascended the Winchester Creek channel to the migrant trap.

The proportion of marked fish that were captured soon after release or were delayed in recapture varied by sample period. While 82% of fish marked after February were recaptured at the screw trap within two days of release, only 57% of fish marked before the end of February were recaptured within two days of release (Figure 3). This suggests early migrants moved downstream at a slower rate or were more likely to swim back upstream of the trap, increasing the probability of recapture at a later date. Fish that migrated in spring did not delay moving downstream and were more likely to be recaptured soon after release.

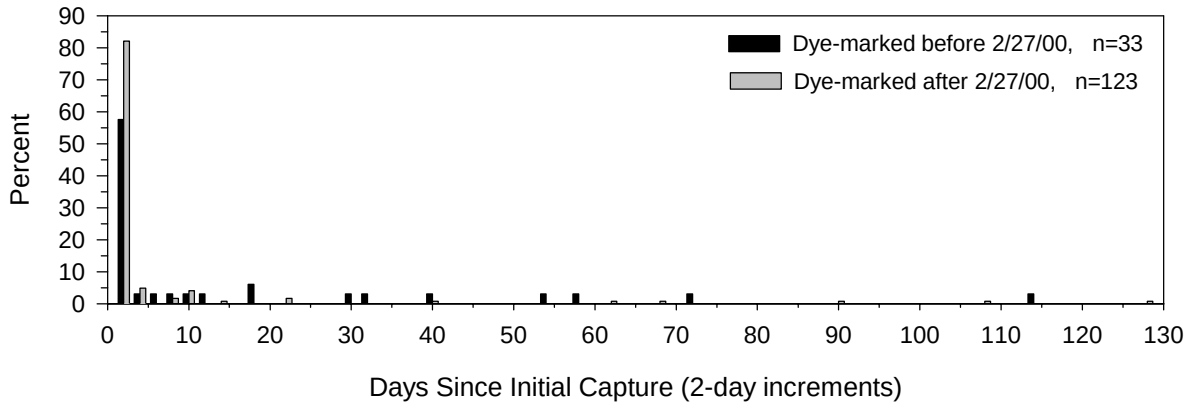

Figure 3. Residence time of juvenile coho dye-marked and recaptured at the migrant trap, Winchester Creek, Oregon.

Age-0 coho were found in Dalton Marsh until mid-June. Seventy percent of marked fry in Dalton Marsh were resident at least 14 days, 25% were resident at least 36 days, and four percent were resident for at least 52 days after being marked.

Fish marked at the migrant trap were also recaptured downstream in the tidal channel and in Kunz Marsh. Recoveries of marked fish indicate that 50% of migrants spent up to 23 days in upper estuarine and associated habitats, 25% resided from 24 to 43 days, and 25% resided from 44 to at least 114 days (Figure 4).

There was also a seasonal component to residence time in upper estuarine habitats. The longest residence times were accrued by fish that migrated prior to March, while spring migrants tended to reside primarily less than a month (Figure 5). The measured residence time for spring migrants may have been skewed toward shorter duration because sampling efforts ended at the end of May, precluding recovery of any fish with longer residence times. However, few coho remained in the upper estuary by late May, thus the higher percentage of spring migrants that reside for only a short period is probably not a sample bias but a behavioral difference.

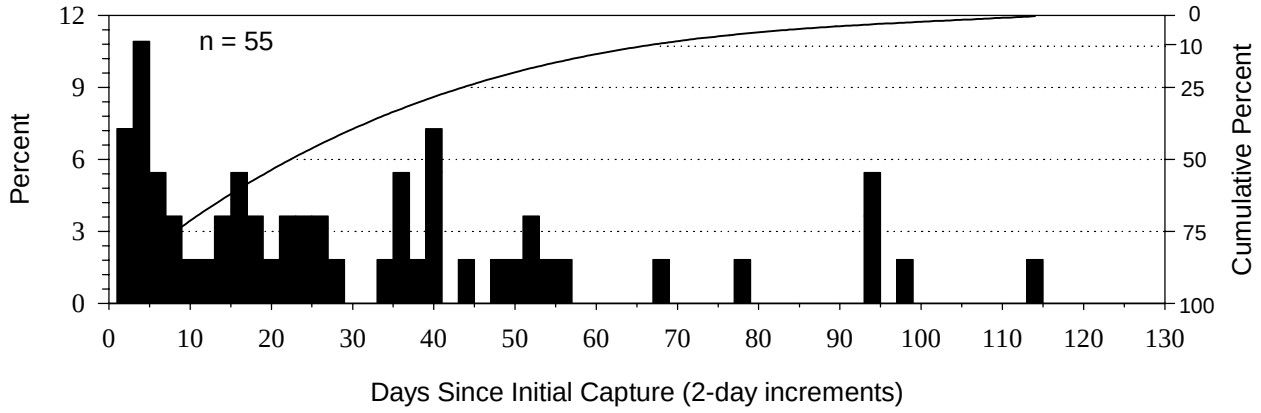

Figure 4. Residence time of juvenile coho dye-marked at the migrant trap and recaptured in Kunz Marsh and the adjacent tidal channel, Winchester Creek, Oregon. Cumulative percent represents a second order linear regression of individual residence times.

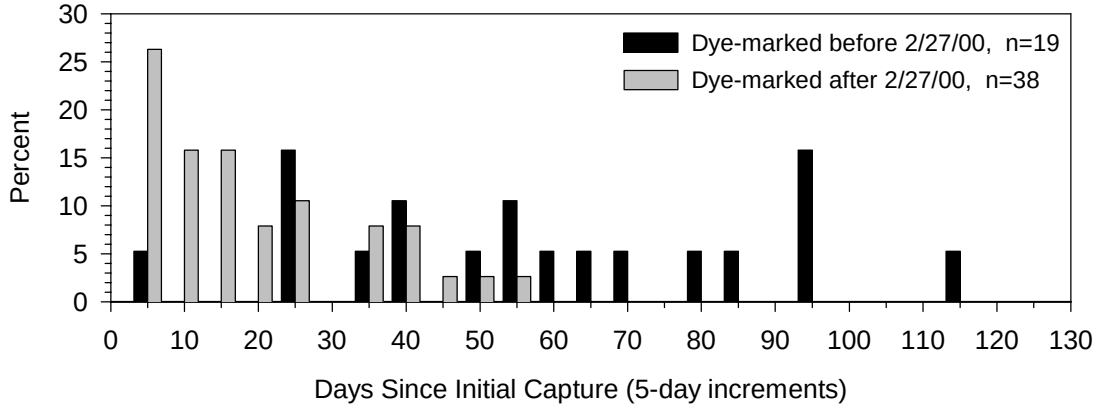

Figure 5. Residence time of juvenile coho dye-marked at the migrant trap or in Cox Pond and recaptured downstream in the tidal channel or in Kunz Marsh, Winchester Creek, Oregon.

A total of 51 juvenile coho were marked in Kunz Marsh and 190 were marked in the adjacent tidal channel. Fourteen of these marked fish (5.8%) were recaptured in those same habitats. Recoveries of marked fish indicate that 50% of migrants spent up to 14 days in these habitats, 25% spent between 15 and 23 days, and 25% of migrants were resident from 24 to at least 38 days (Figure 6).

We calculated a population estimate of 467 juvenile coho resident in Cox Pond in December 1999. Because there is no spawning habitat in Cox Canyon Creek, all of the fish in Cox Pond were migrants from Winchester Creek.

The continued migration of fish into Cox Pond during spring is supported by recoveries of marked fish. In early February, 10% of marked fish in Cox Pond were immigrants marked at the trap in Winchester Creek, and in May this percentage increased to 62.5%. This indicates that some portion of spring migrants from Winchester Creek delayed migration into the lower estuary by moving into upper estuarine tributaries and habitats, including Cox Pond.

Recoveries of fish marked in Cox pond indicate residence times of at least 98 days. The calculated cumulative percentage of residence times suggests that 50% of fish in Cox Pond spent

at least six weeks in residence, while 25 % resided at least two months (Figure 7). Fish marked in Cox Pond were also recaptured in Kunz Marsh below Cox Canyon Creek and upstream at the migrant trap. This suggests a regular movement of fish between the beaver pond habitat and other upper estuarine habitats.

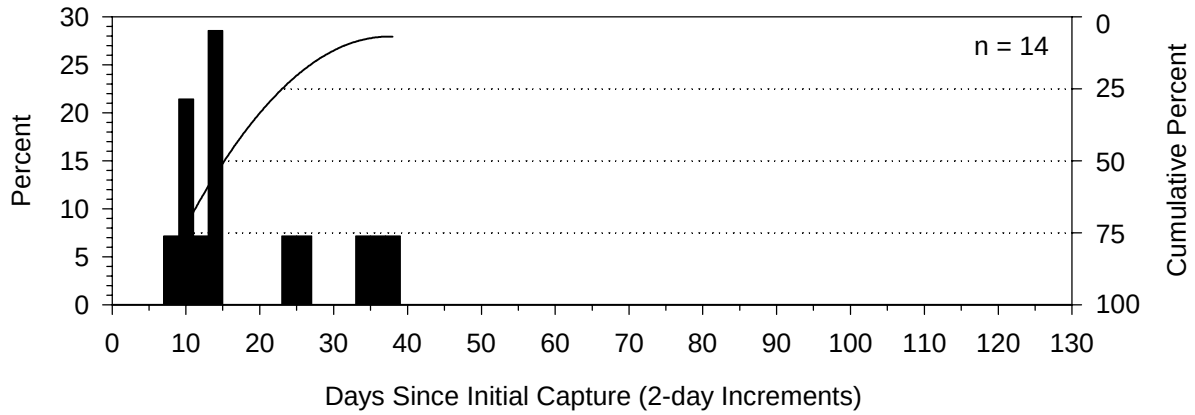

Figure 6. Residence time of juvenile coho dye-marked in Kunz Marsh or the adjacent tidal channel and recaptured in these same habitats, Winchester Creek, Oregon. Cumulative percent represents a second order linear regression of individual residence times.

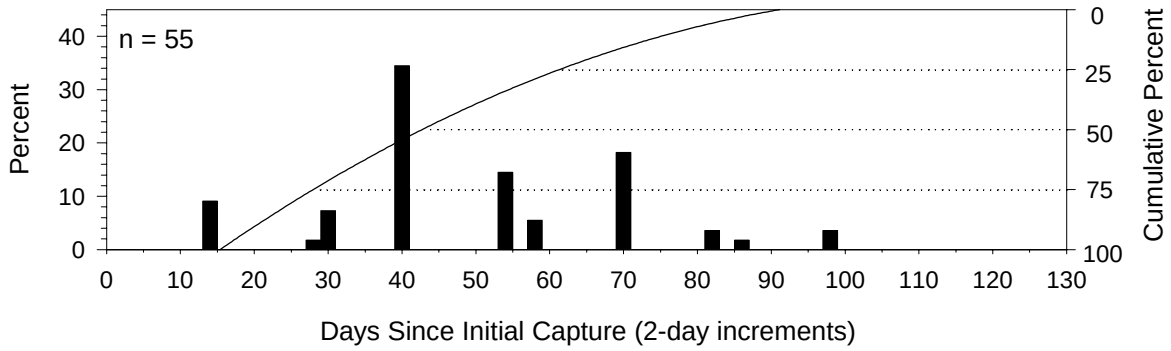

Figure 7. Residence time for marked juvenile coho in Cox Pond for the period of December 17, 1999 to June 1, 2000. The cumulative percent of recaptured fish crosses the x-axis at two weeks because the minimum sample interval was two weeks. Cumulative percent represents a second order linear regression of individual residence times.

Size, Growth Rate and Condition Factor of Migrants and Recaptured Fish

During spring 1999, mean fork length of age-0 coho fry measured at the migrant trap increased from 35 mm in March to 46 mm in early May (Figure 8). A portion of these age-0 migrants moved into Dalton Marsh, 1.4 km below the migrant trap. Fry in Dalton Marsh grew at a faster rate than fry in the upper watershed, reaching a mean of 70 mm by mid-June before leaving this habitat.

During fall, juvenile coho sampled at the migrant trap were significantly larger than fish sampled in the upper watershed (Figure 8). During this same period, juveniles in Cox Pond were

significantly larger than fish from either the migrant trap or the upper watershed, and this size difference was evident through spring 2000 (Figure 9).

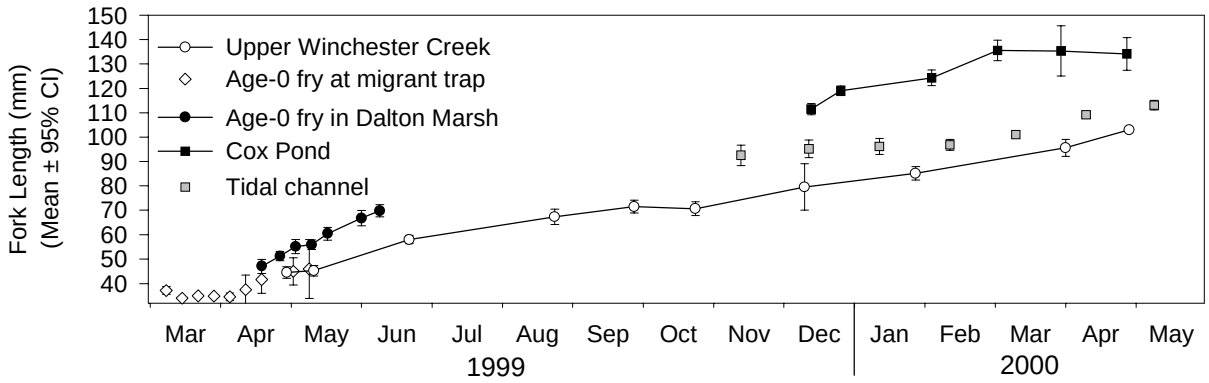

Figure 8. Fork length of 1999 brood juvenile coho in Winchester Creek, by habitat type.

Length-frequency distributions indicate fall migrants did not come from a homogeneously distributed population (Figure 9). By late winter migrants were distributed with a mode between 90 and 100 mm. Figure 9 also shows the consistently larger size of fish in Cox Pond compared to migrants in Winchester Creek.

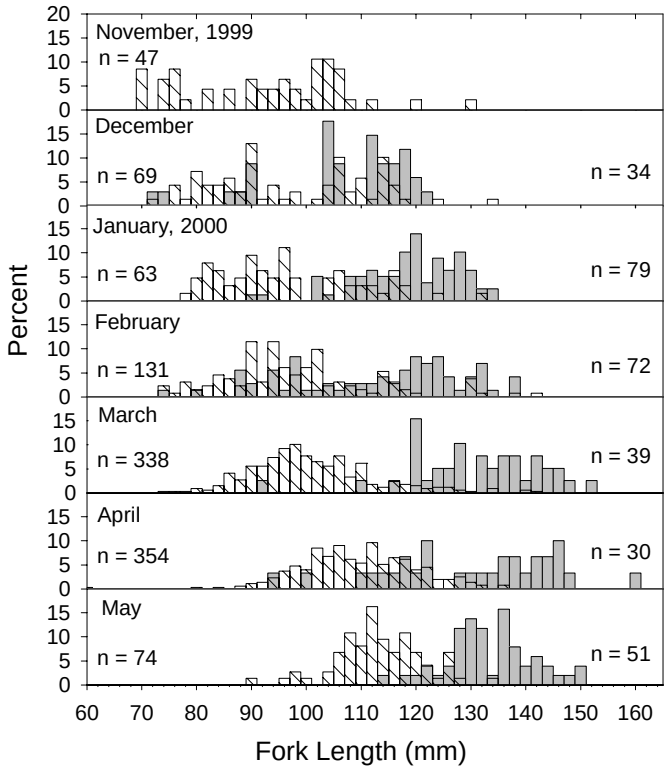

Figure 9. Length-frequency of 1999 brood juvenile coho at the migrant trap (diagonal bars, sample size on left) and in Cox Pond (solid bars, sample size on right), Winchester Creek, Oregon.

The highest growth rate measured was 0.44 mm day^{-1} for fry rearing in Dalton Marsh from April to June, 1999 (Figure 10). Fish marked and recaptured in Cox Pond between December, 1999 and May 2000 grew at a mean rate of 0.30 mm day^{-1}. Growth rate of fish marked at the migrant trap and recaptured in the tidal channel and in Kunz Marsh between November, 1999 and May, 2000 was 0.26 mm day^{-1}. The lowest growth rate recorded was for juveniles that reared in the upper watershed. Between December, 1999 and April, 2000 a growth rate of 0.16 mm day^{-1} was calculated using the difference in mean fork length. Growth in the upper watershed increased slightly to 0.25 mm day^{-1} between April and June, 2000.

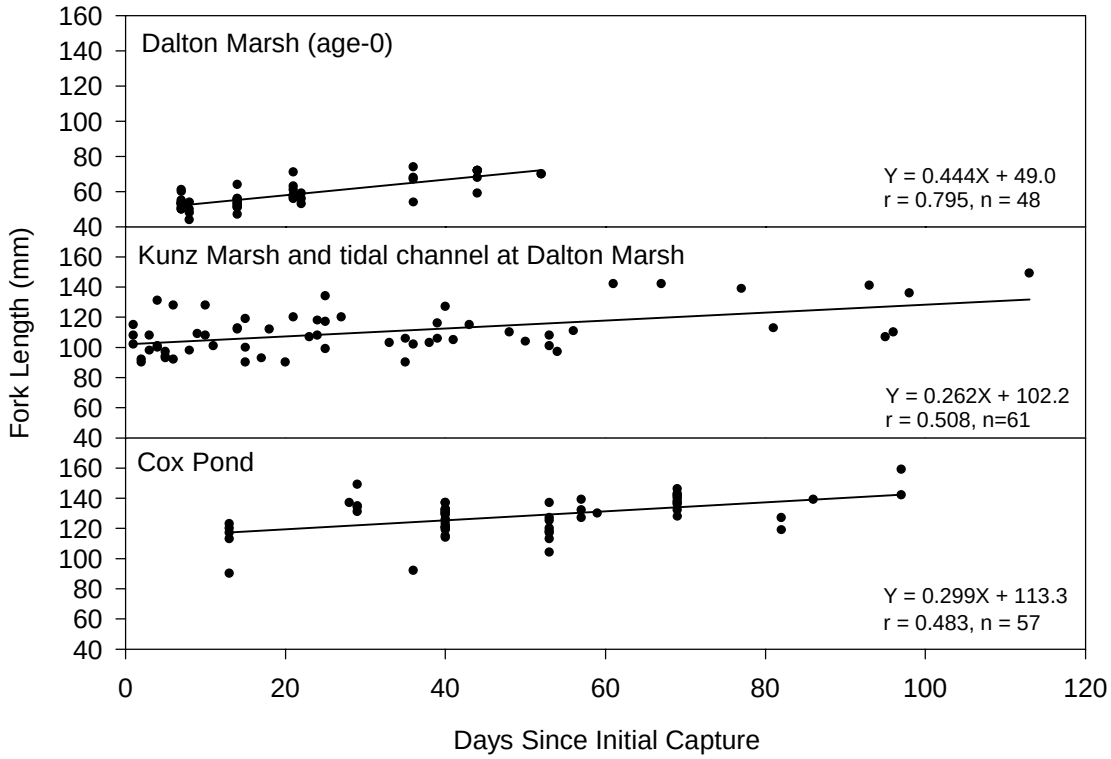

Figure 10. Growth rate of age-0 coho fry fin-marked and recaptured in Dalton Marsh, and dye-marked coho recaptured in tidewater (Kunz Marsh and the tidal channel adjacent to Dalton Marsh) and Cox Pond, Winchester Creek, Oregon.

Condition factor of juvenile coho varied between habitats. The lowest condition factor was observed in fish sampled at the migrant trap while highest condition factors were found in fish residing in the upper watershed in February and fish caught in Kunz Marsh and adjacent tidal channel (Figure 11). Condition factor of fish sampled in other upper estuarine habitats of South Slough had intermediate values.

Fish sampled in Kunz Marsh had significantly higher condition factor than fish sampled in the tidal channel adjacent to Dalton Marsh (P= 0.001). Dye-mark recovery data indicated that fish in Kunz marsh and those in the tidal channel near Dalton marsh were from the same population, thus the difference in condition factor may have represented higher stomach fullness following foraging in the marsh habitat.

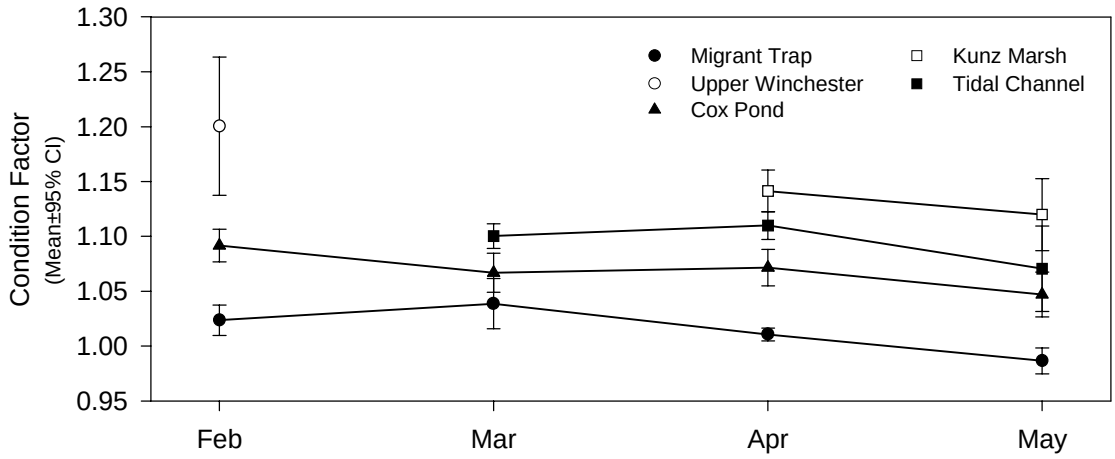

Figure 11. Condition factor of 1999 brood juvenile coho in Winchester Creek, by habitat type.

Discussion

Both the 1998 and 1999 brood of coho began downstream migration to upper estuarine habitats during spring as age-0 fry. The fate of these migrants after spring is not known, but some portion of these early migrants may have re-ascended Winchester Creek to the uppermost tidal reaches as stream flows diminished and temperature and salinity in upper reaches of tidewater increased after May. Age-0 fish that re-ascended the creek would likely have contributed to the migrants measured in the fall, thus the actual percentage of migrants that derive from upstream in the fall may be lower than our estimate. The high growth rate of age-0 fry in Dalton Marsh also suggests that some portion of spring migrants could emigrate from the system as age-0 juveniles, but we have no data to indicate whether these fish make physiological changes characteristic of smoltification.

Downstream migration of juveniles to tidewater in the fall was observed to coincide with increased stream flows, with a peak in late November and early December. Rodgers et al (1987) also found the first of two peaks in migration of coho during November (the second in April) in Knowles Creek, Oregon. Rodgers noted a similar pattern of condition factor, with highest values found in non-migrants in the upper watershed and lowest values in migrating fish. Other physiological traits measured in downstream migrants, including skin guanine levels and gill (Na+K)-ATPase activity, suggested fall migrants in Knowles Creek were not smolts in the process of emigration to the ocean. Rather, fall migrants were considered a portion of the population that moved downstream to better over-winter habitat, where they remained until spring. During spring, physiological changes characteristic of smoltification were found in juveniles during the second peak in migration. Juvenile coho found in the upper estuarine portion of Winchester Creek in the fall may be expressing similar behavior, over-wintering in very productive habitats before emigration from the system as smolts in winter or spring.

The apparent bimodal distribution in length of fish sampled in November and December suggests more than one source for fall migrants. Small fish may be new migrants from the

population found above tidewater. The large fall migrants may represent age-0 fry that migrated during spring or summer to habitats in upper tidewater or lower Winchester Creek and grew at a faster rate than fish that reared upstream (Mason, 1974). This latter interpretation is supported by the faster growth rate of fry observed in Dalton Marsh and other upper estuarine habitats during spring. Further evidence is suggested by the presence of larger fish in Cox Pond in the fall. We did not sample for fish in Cox Pond during summer, but limited sampling of physical parameters suggests that maximum water temperatures and low dissolved oxygen likely exceed tolerance levels for juvenile coho during this period. Fish probably enter Cox Pond in the fall, and the large fish found in November and December may be derived from a population that reared in upper tidewater during summer.

Although mean length of fish in Cox Pond was always greater than in other habitats, the broad range found in December and February suggests continued immigration into this habitat from Winchester Creek. The mode of smaller fish found in April also suggests a continued immigration into the pond during the peak in spring migration in Winchester Creek. Additionally, recoveries of dye-marked fish indicate a regular exchange of fish between Cox Pond and other upper estuarine habitats.

There was an apparent seasonal difference in the tendency to delay out-migration, with longer residence times found for fish that migrated in the fall and early winter. The point at which a fish is ready to emigrate is a function of both size and physiological adaptation to higher salinities (Folmar and Dickhoff, 1980). Fish that migrate downstream in the fall to habitats associated with the estuary clearly grow faster than fish that reside further upstream. If out-migration from the system is due, at least in part, to size, reaching a larger size in the fall may lead to earlier smoltification and emigration. It is not clear whether this behavior may influence survival compared to fish that undergo this process later during the following spring.

Irrespective of season of migration to the upper estuary, most fish appeared to delay migration to the lower estuary by several weeks or in some cases, several months. Higher growth rates were observed in all upper estuarine habitats compared to growth rates found in West Fork Winchester Creek. The opportunity to reach a larger size in upper estuarine habitats before movement to the lower estuary or ocean appears to be the principal functional advantage of delayed migration.

These preliminary data also point to the relative value of different habitats associated with the upper estuary. Fish that foraged in Kunz Marsh for only a few hours at high tide had higher condition factor than fish sampled in the adjacent tidal channel, indicating better forage opportunities in fringing marsh. The consistently large size of fish found in Cox Pond suggests this habitat provides superior forage compared to other habitats. Beaver ponds associated with lowland marsh near head of tidal influence were once common in Oregon estuaries but are now one of the least common habitats. These data suggest that restoration of lowland marsh and reestablishment of beaver ponds has high potential for increasing productivity of estuaries for juvenile coho salmon.

Acknowledgements

Funding to SSNERR for this study was made possible through grants from the Oregon Watershed Enhancement Board and the U.S. Fish and Wildlife Service, Oregon Fish and Wildlife Office, Jobs In The Woods Program.

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