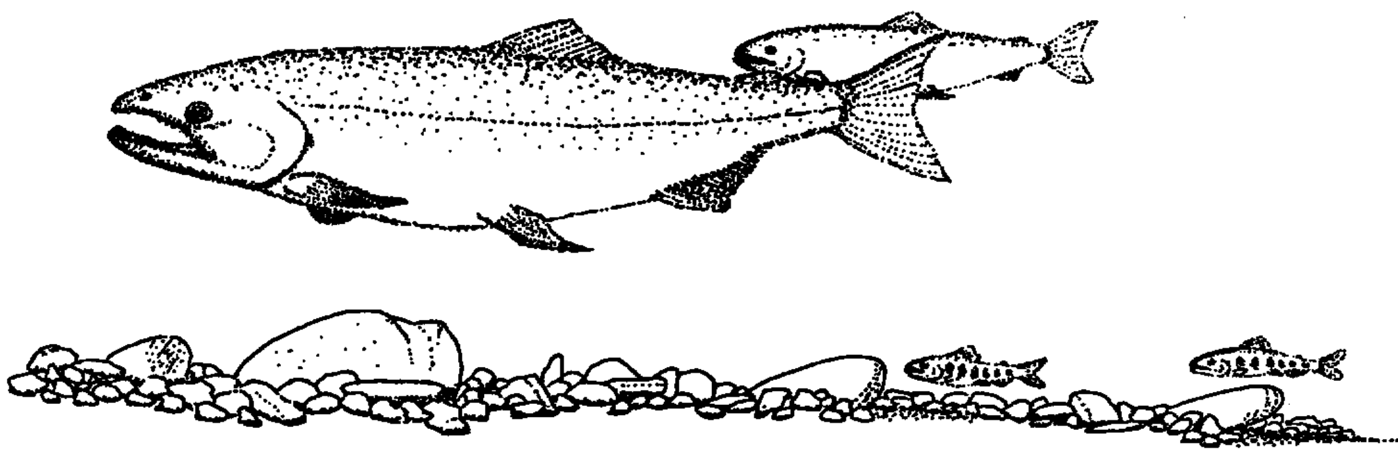
U.S. DEPARTMENT OF THE INTERIOR

FISH AND WILDLIFE SERVICE

EMIGRATION OF JUVENILE CHUM SALMON IN THE ELWHA RIVER AND IMPLICATIONS FOR TIMING HATCHERY COHO SALMON RELEASES



WESTERN WASHINGTON FISHERY RESOURCE OFFICE

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Abstract

The emigration timing and estuarine residence of chum salmon in the lower Elwha River were assessed using fyke netting and beach seining. Emigration was already underway by 21 March 1995, showed bimodal peaks on 1 May and 15 May 1995, and virtually ended by 12 June 1995. Freshwater rearing was believed to occur based on increasing fork lengths of chum fry over the sampling period. A model predicting the time to maximum alevin wet weight (MAWW), and calculation of temperature units, failed to accurately estimate chum salmon emigration in the Elwha River. Differences in intragravel water temperatures at the study site versus temperatures at mainstem sampling locations monitored by the Lower Elwha Tribe, and freshwater rearing by juvenile chum salmon, likely caused the failure of these prediction methods. Only four chum salmon were caught in the limited estuary of the Elwha River, but extensive estuarine residence is suspected based on the size of two of these fish (> 80 mm fork length). No chum salmon fry were observed in the stomach contents of 23 coho smolts and 11 steelhead smolts released from the Lower Elwha Tribe's hatchery and later caught at the mouth of the Elwha River. Although no predation was observed, the limited sample size examined is insufficient to draw strong conclusions. Delaying hatchery releases until June 1 should protect a majority of emigrating chum salmon in the Elwha River.

Emigration of Juvenile Chum Salmon in the Elwha River and Implications for Timing Hatchery Coho Salmon Releases

prepared for the

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Introduction

Based on spawner surveys completed over the past 40 years, Elwha River chum salmon (*Oncorhynchus keta*) appear to be declining (Wunderlich et al. 1994). Lack of survey information and high variability in adult chum salmon counts resulted in the health of this stock being listed as "unknown" in the SASSI report (WDF et al. 1993). One possible cause of this decline is the release of hatchery coho smolts (*O. kisutch*) from the Lower Elwha Tribal Hatchery located at the mouth of the Elwha River. A better understanding of the emigration timing of Elwha chum salmon would assist planning hatchery coho salmon releases to limit potential predation on this stock, and improve prospects for restoring Elwha chum salmon (Olympic National Park 1996).

Unlike coho salmon, which spend 1-2 years in freshwater, chum salmon emigrate from streams shortly after emerging from the gravel, usually spending less than three months in freshwater (Salo 1991). As a result, chum salmon generally enter the estuary at a size less than 55 mm fork length and are susceptible to predation from a large number of birds and piscivorous fish, including coho salmon smolts. Chum salmon fry may remain in the shallow near-shore areas of estuaries for up to 18 days (Healey 1979). Mortality rates of juvenile chum salmon entering the marine environment may exceed 40% per day (Bax 1983). Much of this mortality appears to be size-selective mortality during the period when chum salmon fry move from shallow near-shore estuarine areas to open water neritic habitats at 45-55 mm fork length (Healey 1982). During this period of mortality, chum salmon fry would most likely be susceptible to depensatory mechanisms of mortality as a result of predation (Neave 1953).

Coho salmon smolts, particularly hatchery smolts, have been implicated in the decline of natural chum and pink (*O. gorbuscha*) salmon stocks (Johnson 1973; Ames 1983; Crain 1992). The early release timing of hatchery coho smolts is believed to be the primary factor contributing to interspecific competition between hatchery coho salmon and wild pink and chum salmon (Johnson 1973). Early release of coho salmon smolts is hypothesized to reduce or eliminate the temporal isolation normally observed between these species (Holtby et al. 1989).

Information pertaining to the emigration timing and estuarine residence of chum salmon would be valuable for reducing interspecific interactions between chum and coho salmon. Chum salmon hatching and emigration are related to stream temperatures and stocks are often adapted to local conditions (Beecham and Murray 1987; Holtby et al. 1989; Murray and McPhail 1988). However, laboratory models may not accurately predict emergence of fry under natural conditions (Crisp 1988) and stream temperatures may not represent actual incubation temperatures in the intragravel environment (Shepherd et al. 1986). Thus, the relationship of chum salmon emigration to stream temperatures in the Elwha River would be valuable information for planning releases of coho salmon to minimize interspecific competition.

The objectives of this study were to: 1) determine the emigration timing of chum salmon in the Elwha river, 2) evaluate the relationship of chum salmon emigration and river temperatures, 3) determine estuarine residency time of Elwha River juvenile chum salmon, and 4) assess predation of juvenile chum salmon by hatchery coho salmon and steelhead.

Study Area

This study was completed in a side channel of the lower Elwha River and the Elwha River estuary (Figure 1). The Elwha River drains the north slope of the Olympic Mountains, entering the Strait of Juan de Fuca just west of the city of Port Angeles. The side channel is located on the west side of the river and begins approximately 3.3 km above the Strait and re-enters the river at approximately river km 1.4. The substrate is primarily coarse cobble with sand in slack water areas and some gravel located in pool tail-outs. Riparian vegetation is composed primarily of red alder (*Alnus rubra*) and salmon berry (*Rubus spectabilis*). Discharge in the side channel varies with river discharge and ranged from approximately 0.14 to 1.7 m^3/s (4.9 to 60 cfs) during this study. The river flows directly into the Strait of Juan de Fuca and lacks a well defined estuary. Bosco Slough, located on the east side of the main channel, is the most well defined estuary of the river. During high tide, salt water enters the slough and a few estuarine species have been observed in this habitat (Doug Morrill, Lower Elwha Tribe, personal communication).

Materials and Methods

Emigration

Emigration timing of Elwha River chum salmon was assessed by fyke netting the downstream end of the former Washington Department of Fish and Wildlife (WDFW) index side channel (Figure 1), which was the primary spawning ground of chum salmon the previous fall (Hiss 1995). The fyke net was fished weekly from 21 March 1995 to 12 June 1995 at one location (primary trap site), except on 24 April when the trap was moved downstream (alternate trap site) due to low flow conditions (Figure 1). The net fished a cross section of approximately 1.2 m and fished the entire vertical water column. The trap was installed approximately one hour before sunset and fished until the next morning, except on 21 March 1995, when it was fished only until midnight. The trap was checked one to two times during the night depending on the number of chum salmon emigrating and river discharge. All species were netted from the live box and enumerated. Up to 25 fish of each salmonid species were anesthetized using MS-222 (tricaine methanesulfonate), measured for fork length (nearest mm), then released downstream of the trap upon recovery.

Discharges through the side channel and the fyke net were measured each week to determine if the proportion of the channel discharge sampled by the fyke net changed drastically during the study. For this purpose, stream width was measured and divided into 1.2-m cells. Water depth and mean water column velocity were measured in the center of each cell. Water depth was measured using a surveyor's rod and mean water column velocity was measured using a Swoffer model 2100 flow meter. Discharge of each cell was calculated by multiplying cell depth by cell width by current velocity in the center of the cell. Total channel discharge was then calculated by summing the discharge of all the cells. Discharge through the trap was calculated in the same manner, except the cell width was the width of the trap (1.2 m).

Total chum salmon emigrating during each sampling date were estimated by adjusting catch data using the proportion of side channel discharge fished by the fyke net. The proportion of the side channel discharge fished by the fyke net was calculated by dividing the estimated discharge through the trap by the estimated discharge in the side channel. Total chum salmon emigration was then calculated by dividing the number of chum salmon caught in the fyke net by the proportion of the discharged fished. This method was modified for data collected on 23 April, because the dishcarge fished by the trap was not measured. Therefore, the average proportion of side channel discharge fished by the fyke net over the study period was used to estimate total chum salmon emigration for this date.

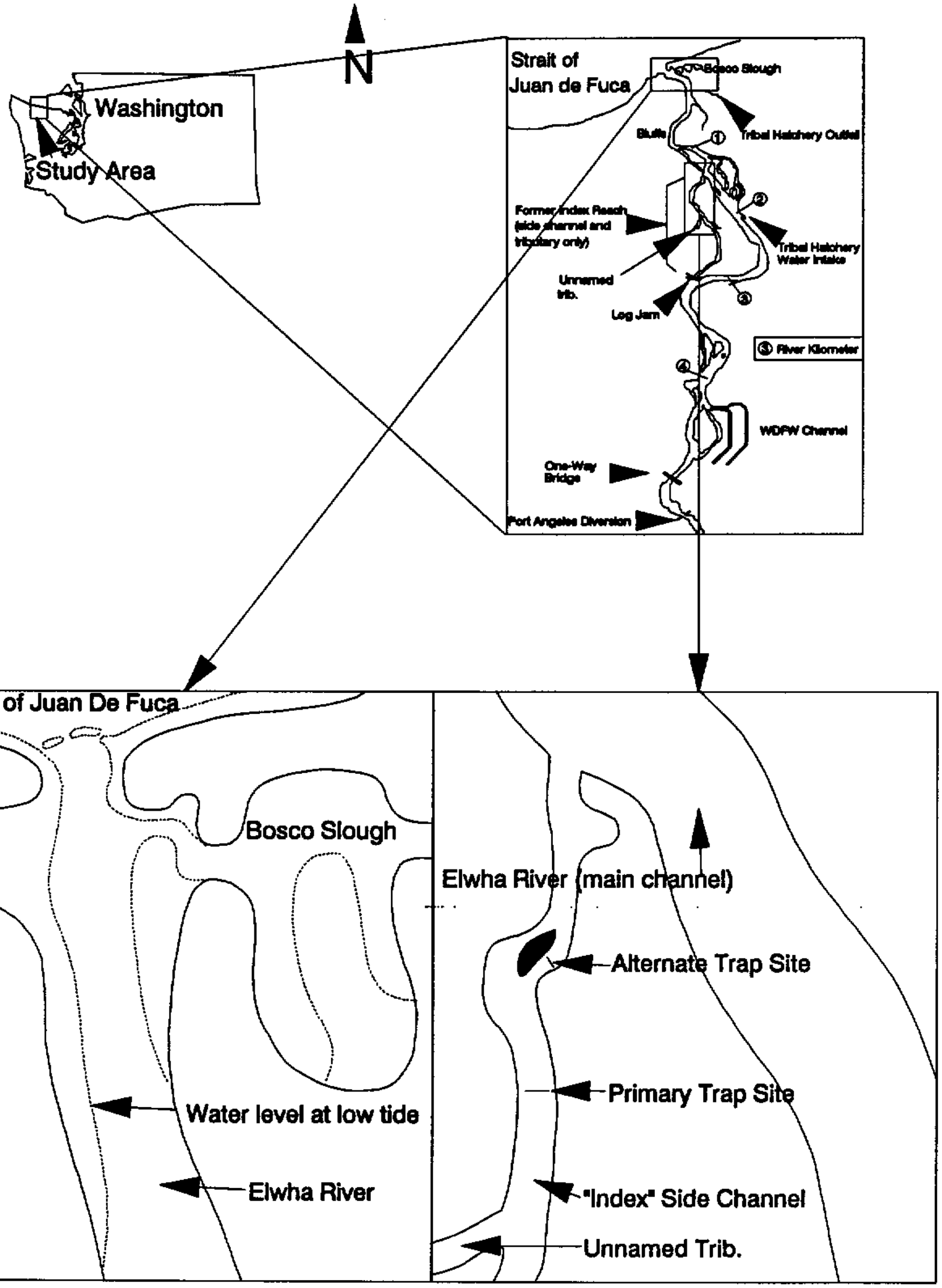

Figure 1. Locations in the Elwha River basin where chum salmon were sampled using fyke nets and beach seines.

In an effort to find a tool to estimate emigration timing, the initiation, peak, and termination of chum salmon emigration from the side channel were assessed using a model (equation 1) relating temperature (T) and time, to maximum alevin wet weight (t_{MAWW}) (P. Rombough, Zoology Dept., Brandon University; Brandon, Manitoba; published by Holtby et al. 1989).

$$(1) \qquad \log t_{MAWW} = 5.6677 - 0.1008 * T (n=9; r^2=0.96)$$

This estimate was calculated using the mean temperature from: (1) the time between the first observed spawner and the first emigrant; (2) the time between median spawning and the median emigration; and (3) the time between the last observed spawner and the last emigrant. We then calculated the estimated time (days) to maximum alevin weight and compared it to the actual number of days between the first spawner and first emigrant, median spawning and median emigration dates, and the last spawner and last emigrant.

A second theoretical tool examined for estimating chum salmon emigration was temperature units. Temperature units were calculated by summing river temperatures over the desired period (e.g., spawning to emergence) for the three time periods listed above. Consistency of temperature units among the three periods would suggest temperature is a primary factor determining emigration.

Estuarine Residency

Estuarine residency was assessed from weekly beach seining at several locations in Bosco Slough and the mouth of the Elwha River (Figure 1). Seining was conducted after dark during the first few surveys and just prior to dark thereafter. The beach seine was approximately 8.8 m long and 1.7 m deep with a mesh size of approximately 3 mm. On one occasion a larger seine was used, which was 29 m long and 2.4 m deep with a mesh size of 1.25 cm, except for the 8.8-m bunt which had a mesh size of 1.6 mm.

Hatchery Releases

Initially, the Lower Elwha Tribe planned to release their hatchery coho salmon and steelhead (*O. mykiss*) smolts after the expected completion of the chum salmon emigration (1 June). However, due to water quality concerns and the readiness of the smolts at the hatchery, the tribe released its smolts between 4 May and 12 May. To assess predation we sampled the stomach contents of hatchery coho salmon and steelhead smolts caught during our normal estuary seining activities on 5 May 1995. Coho salmon and steelhead smolts were anesthetized using MS-222, weighed (nearest 0.1 g), and measured for fork length (nearest mm). Stomach samples were collected using pulsed gastric irrigation (Foster 1977) and passed through a 0.3-mm sieve. Contents were examined visually and salmonid (and salmonid remains) and large non-salmonid contents were noted. After stomach samples were collected, the fish were placed into recovery buckets and subsequently released.

Results and Discussion

Emigration

The proportion of the discharge fished by the fyke net was relatively stable (Mean=0.14, SD=0.032) during the study period except on 24 April 1995, when nearly all the channel discharge (76%) was sampled (Figure 2). This occurred because low flows forced us to move the trap to an alternate site (Figure 1). Although actual catch on this date was the largest recorded, estimated emigration was not the largest estimate (Figure 3).

A total of 902 juvenile chum salmon were trapped in the index side channel (Figure 3). The first emigrants were caught during the first night of trapping (21 March 1995) and one emigrant was caught on the last night of trapping (12 June 1995). Peak emigration occurred between 1 May and 15 May and was somewhat bimodal. Although fish were caught during the first night of trapping, their size suggested that emigration began only shortly before this date. The average fork length on 21 March was smaller than chum fry captured during subsequent sampling periods. One of the six fish caught on 21 March also had not completely absorbed its yolk sac, suggesting that it may have been scoured from the gravel. Flows on 21 March were the highest observed during the study and had the potential for scouring redds. Emigration likely ended just after the last survey. No chum fry were observed during a foot survey of the index side channel on the last survey, while many chum salmon were normally observed on previous foot surveys.

The relationship between temperature and maximum alevin wet weight (equation 1) did not accurately predict the timing of the first emigrant or peak emigration. Emigrants were first caught on 21 March but the model predicted 28 April as the date of maximum alevin wet weight. The maximum alevin wet weight model also predicted median emigration date of 1 June, but the observed median emigration date was nearly one month sooner (1 May). This contrasts with the results obtained by Holtby et al. (1989) who found this relationship to predict median emigration of chum salmon from Carnation Creek, B.C. within 3 days in 9 of 17 years and within 10 days over the 17-year period. However, the timing of the last emigrant was estimated within four days (actual 12 June; estimate 8 June). One might use this model to estimate the termination of chum fry emigration, which is the date actually desired for timing hatchery coho smolt releases. However, the lack of a relationship between the timing of the first emigrant and peak emigration casts doubt on the model's accuracy.

There also was no consistency in the number of temperature units acquired among the three time periods described above. One thousand two hundred and seven (1,207) temperature units were acquired from the first observed spawner to the first emigrant. However, 1,264 and 1,470 temperature units were acquired from peak spawning to the first and second peak of emigration, respectively. Just over 1,800 temperature units were acquired between the time of the last observed spawner and the last observed emigrant. The lack of consistency among the number of temperature units acquired during the sampling periods also casts doubt on their predictive value.

Two factors could be responsible for the lack of a relationship between emigration timing of Elwha chum salmon and temperature. First, water temperatures measured in the water column may not represent those in the intragravel environment (Shepherd et al. 1986). Temperature data used in this study were collected with a thermograph in the mainstem Elwha River several km upstream of the index side channel, and may not have represented true temperatures in the side channel. Moreover, groundwater tributaries enter the side channel and these ground water sources are warmer than the mainstem Elwha River (Doug Morrill, Lower Elwha Tribe, personal communication). This would result in an earlier emigration than predicted by either model.

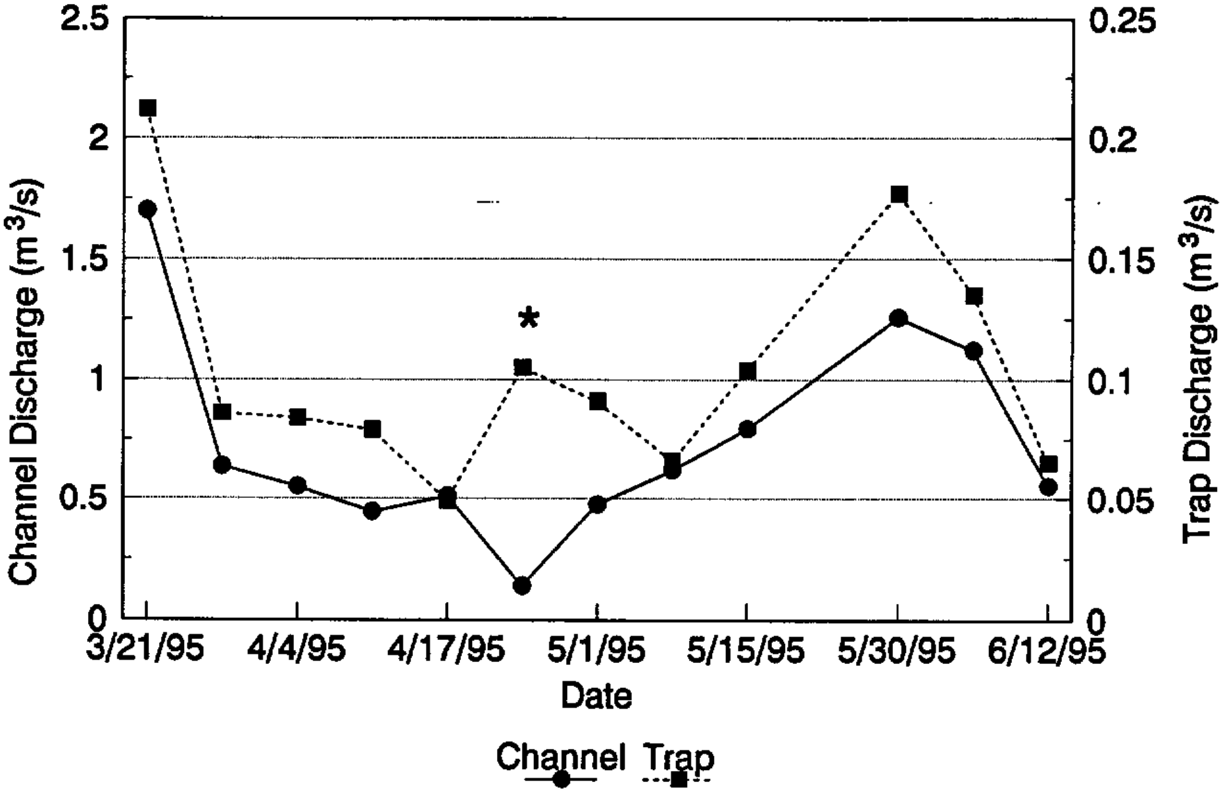

Figure 2. Trap and side channel discharge during chum emigration surveys. *The larger amount of water fished by the trap during this survey resulted from changing the trap's location due to low flow conditions (Figure 1).

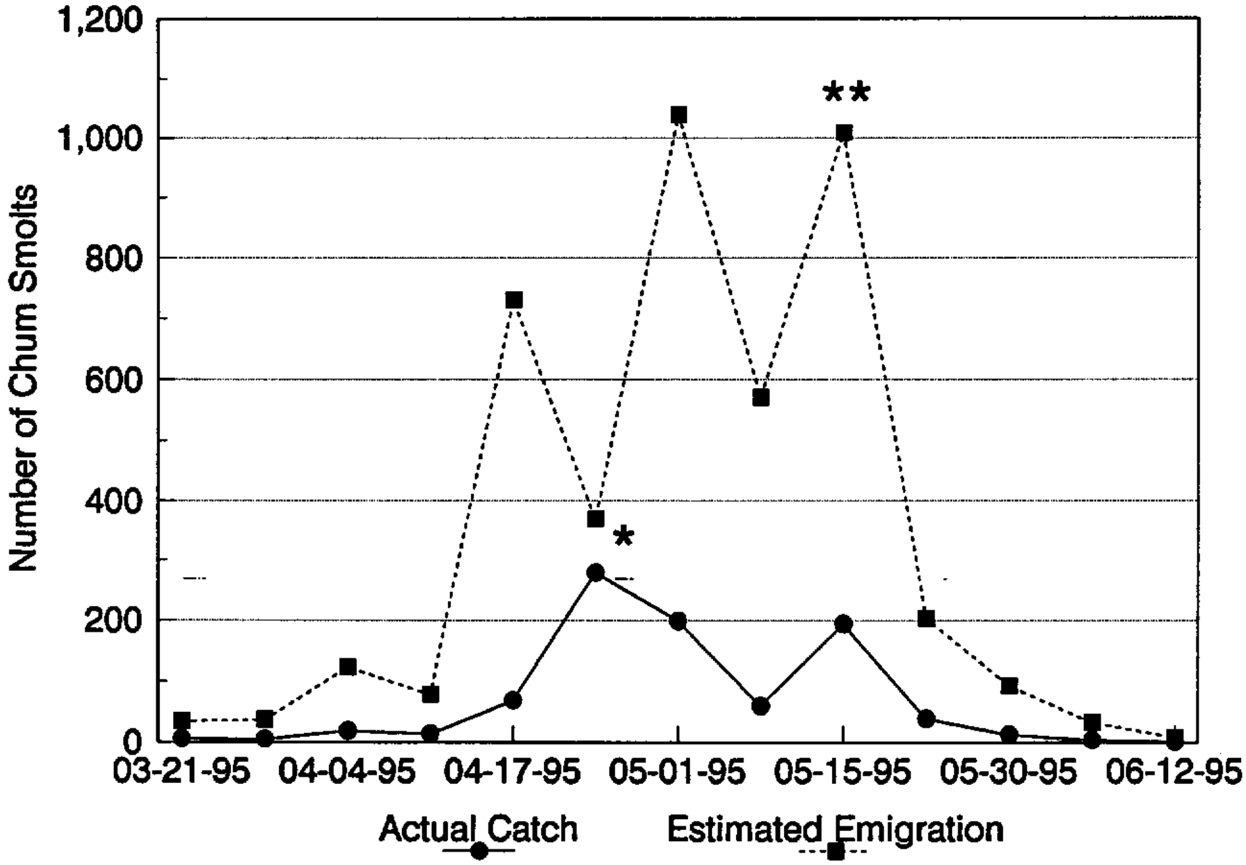

Figure 3. Daily catch and estimated emigration of juvenile chum salmon from the index side channel of the Elwha River. *Estimated catch was low because of a change in the trap location on this date (see Figures 1 and 2). **Smolt estimate based on mean percent of water column fished over the study (excluding the alternate site fished on 23 April) because trap discharge was not measured on this date.

Second, the lack of an emigration temperature relationship could be the result of instream rearing by chum fry, which would have delayed emigration. It appears that some stream rearing occurred, based on the size of juvenile chum salmon emigrating from the side channel (Figure 4). During the first eight weeks of trapping, the mean fork length of emigrating chum salmon ranged from 35 to 40 mm. Thereafter, mean fork length steadily increased to a maximum size of approximately 52 mm by the last survey on 12 June 1995. Although chum salmon are commonly thought to emigrate immediately following emergence, there is some evidence of freshwater rearing and feeding (Mason 1974).

Estuarine Residency

Very limited information was obtained from this study regarding estuarine residency of juvenile Elwha River chum salmon. Only four juvenile chum salmon were captured during seining at the mouth of the river and in Bosco Slough. Two of these were caught on 15 May 1995, one from Bosco Slough and the other from the mouth of the river (Figure 5). The size of these two fish (42 and 38 mm) does not suggest extensive estuarine residency prior to their capture. Two additional chum salmon were caught on the last sampling day (12 June 1995) at the river mouth (Figure 5). The size of these two fish (80 and 88 mm) suggests extensive estuarine or near-shore residency. Other species caught during seining at the river mouth and in Bosco Slough included: stickleback (*Gasterosteus aculeatus*), sculpins (*Cottus* spp.) Starry Flounder (*Platichthys stellatus*), chinook salmon (*O. tshawystcha*), coho salmon, steelhead, cutthroat trout (*O. clarki*), and zero age trout (*O.* spp.). Total numbers of each species caught during this study are listed in Appendix A.

Estuarine residency of chum salmon is highly variable, ranging between 0 and 18 days, with early emerging fry exhibiting longer residency times (Healey 1979). In Puget Sound, chum salmon begin to move offshore at 45-55 mm fork length (Simenstad et al. 1980; Simenstad and Salo 1982). The small size (< 40 mm fork length) of early emigrant chum salmon from the Elwha River suggests that these fry require some near-shore rearing prior to moving offshore. However, by mid-May, Elwha emigrants were large enough (35-59 mm; 62% > 40 mm) to move directly offshore based on these size criteria. The few fish caught during our surveys suggest that few chum salmon were rearing in the limited estuary of the Elwha River. However, the sampling gear available for this study was relatively small for the sampling area. Also, a significant portion of the mouth of the river could not be sampled due to fast current velocities. These factors, along with the expected low number of emigrants resulting from the few spawners present during the fall of 1994 (Hiss 1995), suggest the probability of capturing chum salmon fry was quite low. However, the presence of large chum salmon on the last survey date suggests that extensive near-shore rearing may have occurred. Their presence, along with that of other larger salmonids, suggests that our sampling procedures were minimally adequate for capturing chum salmon fry, and extensive estuarine rearing by a significant portion of the emigrant population should have been detected.

Hatchery Releases

No evidence of coho salmon or steelhead predation on chum salmon was observed following the hatchery release. Twenty-two coho salmon (Mean Fork Length = 149.8 mm, SD=18.66) and nine steelhead (Mean Fork Length = 223.1 mm, SD=40.52) were collected at Bosco Slough and the mouth of the Elwha River on 8 May 1995. None of these fish had eaten any juvenile chum salmon. Many of the coho smolts sampled had empty foreguts, while the remaining fish had eaten terrestrial, freshwater and marine invertebrates. One coho (Fork Length 133 mm), two steelhead (Mean Fork Length = 193.5 mm, SD=31.5), and three cutthroat trout (Mean Fork Length = 165 mm, SD=17.15) were collected on 12 June 1995. Again no juvenile chum were observed in the stomachs of any of these fish. However, no chum salmon fry were caught during any of these surveys, so their availability as forage items is unknown.

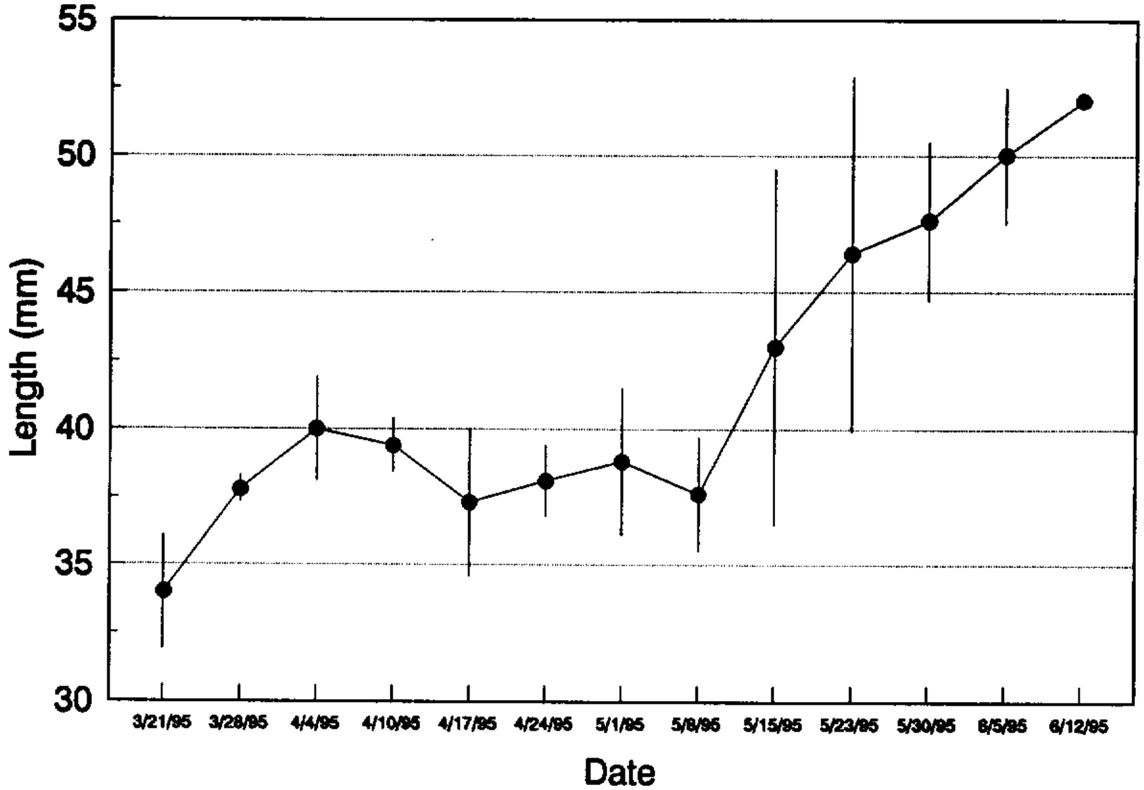

Figure 4. Mean length (+/- SD) of juvenile chum salmon caught emigrating from the index side channel of the Elwha River.

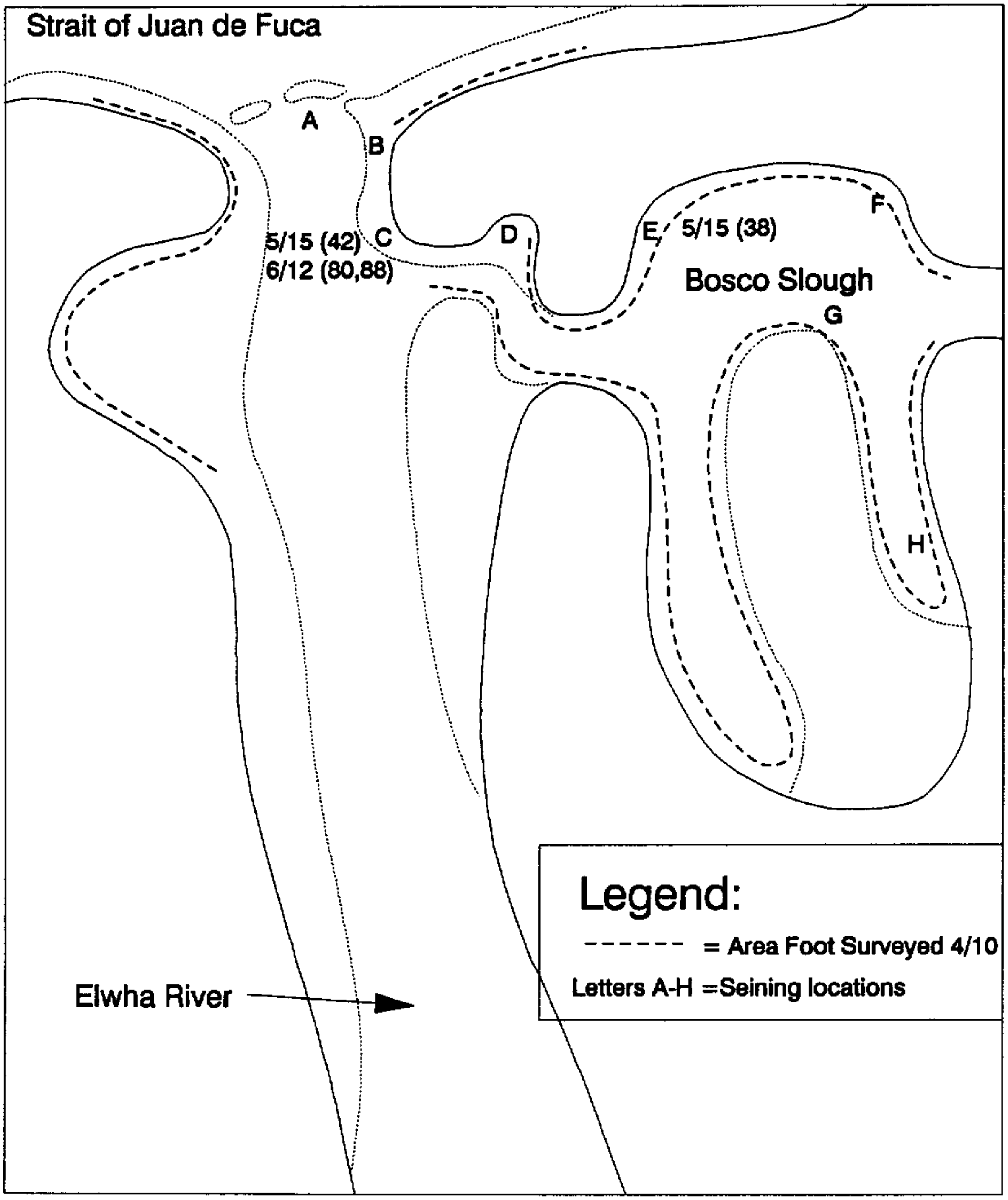

Figure 5. Locations where beach seining and foot surveys occurred at the mouth of the Elwha River and in Bosco Slough. Locations and dates of actual fish captures are noted (fork lengths are in parenthesis). Survey dates at each location were: (A) 4/24, 5/8; (B) 3/28; (C) 3/28, 4/4, 4/10, 4/24, 5/15, 5/30, 6/5, 6/12; (D) 3/21, 4/4, 6/5, 6/12; (E) 4/24, 5/8, 5/15, 5/30, 6/5, 6/12, (F) 4/10, 4/24, 5/1, 5/15, 5/30, 6/5, 6/12; (G) 4/10; (H) 4/24.

Juvenile coho salmon, especially hatchery smolts, have been considered a primary cause of mortality in chum salmon in marine waters (Allan 1974; Heiser and Finn 1970; Johnson 1973; Parker 1971; Walker 1974). However, most of this information is based on observational data (Allan 1974; Heiser and Finn 1970; Parker 1971; Walker 1974) or relationships between hatchery coho salmon production and a decline of nearby chum salmon stocks (Johnson 1973). In contrast, concrete data on the presence of chum salmon in the stomachs of coho salmon in marine envirionments is limited (Murphy et al. 1988; Simenstad and Kinney 1978). Only one field study was located documenting the presence of chum salmon predation by coho salmon (Hargreaves 1988). Nearly 600 coho salmon stomachs were sampled but only three chum salmon were observed. However, there also were very few chum salmon present in the study area (5 chum salmon caught during sampling periods). Other extensive field surveys have found no evidence of predation on chum salmon fry by coho smolts (Miller et al. 1977; Murphy et al. 1988; Simenstad and Kinney 1978). In contrast to marine environments, coho salmon have been observed to be major freshwater predators of chum salmon fry during their downstream migration (Hunter 1959; Fresh and Schroder 1987).

The emigration timing and growth rate of chum salmon reduce predation risks from wild coho smolts. Emigration timing of chum and coho salmon normally provides temporal isolation between these species (Holtby et al. 1989; Murphy et al. 1988), allowing chum salmon fry in the estuary to attain a size large enough to avoid predation by coho salmon smolts. Chum salmon growth rates have been estimated at 6% of body weight per day (Healey 1979), and 0.4 mm (Murphy et al. 1988) to 1.5 mm (Healey 1978) fork length per day. The maximum ingestible prey size of coho salmon is between 42% (Sibert and Parker 1972) and 51% of its body length (Barraclough 1967; Barraclough and Fulton 1967). Assuming a growth rate of 1 mm/day, 40 mm chum salmon entering the estuary 1 May (peak emigration) would be 55 mm by 15 May which is large enough to avoid predation by 100 mm coho smolts. However, the mean fork length of coho smolts sampled on 5 May was 149 mm. These smolts are potential predators of chum salmon fry up to 70 mm fork length, or 15 mm larger than the mean length of chum salmon in mid May.

Based on data collected during this study and literature pertaining to coho salmon predation on chum salmon, delaying the release of coho salmon from the Lower Elwha Tribal Hatchery until 1 June should protect a majority of Elwha River chum salmon. Those chum salmon that have not emigrated by this date are generally large enough to move directly into offshore habitats and likely would spend little time in the estuarine environment. Delaying coho smolt releases until 1 June could present water quality concerns for the hatchery as it did during the spring of 1995. This water quality concern could be eliminated with the installation of chillers (Doug Morrill, Lower Elwha Tribe, personal communication). If chillers are not installed, release of coho smolts could occur earlier with limited impact on chum salmon, assuming that coho smolts released from the hatchery move directly to the marine environment. However, hatchery releases should not occur until the last week of May to avoid the peak emigration of chum salmon fry, based on the 1995 study results.

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Appendix A. Freshwater and marine fish species caught by beach seines at the mouth of the Elwha River and in Bosco Slough.

Date	Chum Salmon	Coho Smolts	Coho Yearling	Sculpin	Starry Flounder	Steelhead	Stickle back	0+ Trout	Chinook	Cutthroat
3/21/95	0	0	0	0	0	0	0	0	0	0
3/28/95	0	0	0	2	1	0	0	0	0	0
4/4/95	0	0	0	66	0	0	0	0	0	0
4/10/95	0	0	0	8	0	0	1	0	0	0
4/17/95	N/E[1]	N/E	N/E	N/E	N/E	N/E	N/E	N/E	N/E	N/E
4/24/95	0	0	0	7	0	1	1	0	0	0
5/1/95	N/E	N/E	N/E	N/E	N/E	N/E	N/E	N/E	N/E	N/E
5/8/95	0	22	0	3	0	9	2	0	0	0
5/15/95	2	0	0	11	0	0	0	0	0	0
5/23/95	N/E	N/E	N/E	N/E	N/E	N/E	N/E	N/E	N/E	N/E
5/30/95	0	0	0	6	0	0	2	4	3	0
6/5/95	0	0	0	12	0	0	0	0	0	0
6/12/95	2	0	29	3	0	2	1	0	1	3
TOTAL	4	22	29	118	1	12	7	4	4	3

[1]No effort