Distribution and Residence Times of Juvenile Fall and Spring Chinook Salmon in Coos Bay, Oregon

Joseph P. Fisher
William G. Pearcy
College of Oceanography, Oregon State University
Corvallis, Oregon 97331

Abstract.– Peak beach-seine catches of small (60–120 mm FL) juvenile fall chinook salmon in Coos Bay occurred about 30–45 days after peak seine catches farther upstream in the Coos and Millacoma Rivers. The average time between release and capture in the bay of marked hatchery fall chinook salmon was about 30 days, but ranged up to 83 days. Thus, many small hatchery and wild fall chinook salmon remained in Coos Bay for about 1 month before entering the ocean. Most captures of large (123–156 mm mean FL) tagged spring chinook salmon released directly into the bay occurred within 10 days following release, indicating a shorter period of residence in the bay for spring chinook salmon than for fall chinook salmon. Catches of juvenile spring chinook salmon were very patchy. Potential for competition between juvenile fall and spring chinook salmon in Coos Bay may be reduced because of differences in the timing and locations of maximum abundance of these two groups. Finclipped fall chinook salmon grew at least 0.2–0.5 mm per day.

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Estuaries are important rearing habitats for subyearling chinook salmon (Healey 1982, Reimers 1973, Myers 1980, Nicholas and Hankin 1988, Levy and Northcote 1982). Residence in estuaries of subyearling chinook salmon can be as long as 3 months or more (Reimers 1973, Myers 1980). Growth rates of subyearling chinook salmon are high in some estuaries (Healey 1980, Levings et al. 1986, Argue et al. 1986), but low in others, perhaps because of competition for food (Reimers 1973, Neilson et al. 1985). Because of the long period of residence and active feeding of juvenile chinook salmon in estuaries, the release of large numbers of hatchery chinook salmon into a system could impact survival and growth of wild fish. The interactions among groups of chinook salmon depend on their overlap in the estuary in time and space.

Many large subyearling spring chinook salmon smolts were released in 1987 into Coos Bay, Oregon, by Anadromous, Inc., a private salmon ranching facility. These fish ranged from about 120 to 160 mm mean fork length (FL) and were generally larger than wild subyearling chinook salmon found in Oregon estuaries (Reimers 1973, Myers 1980, Nicholas and Hankin 1988). The large spring chinook salmon may compete with smaller fall chinook salmon for estuarine resources. However, estuarine dependency and emigration rates of spring and fall chinook salmon in Coos Bay are not known. To assess the potential for competition between juvenile spring chinook salmon released by Anadromous, Inc. and fall chinook salmon, we studied their temporal and spatial overlap in beach-seine samples.

Methods

We collected juvenile chinook salmon in Coos Bay (lat. 43°21'N, long. 124°20'W) with a 60 × 2.5 m beach seine between 25 April and 10 October 1987. The seine had 19- and 13-mm mesh (stretch-measure) in the wings and bunt, respectively. The net was set with the current using a 6.1-m dory powered by a 50 hp outboard motor. Juvenile salmon were counted, measured, and checked for fin-clips immediately after capture. When catches were large, juvenile salmon were kept alive in a floating net pen during processing. Salinity was estimated with an American Optical (Model TS) refractometer to the nearest ‰ and temperature measured to the nearest 0.1°C.

Five stations were sampled regularly (Fig. 1). Stations 1, 2, 3, 4, and 5 were 2.0, 3.3, 6.5, 9.8, and 14.8 km, respectively, from the mouth of the bay. The Anadromous, Inc. release facility was located on North Spit between sites 3 and 4. On most dates each station was sampled twice.

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

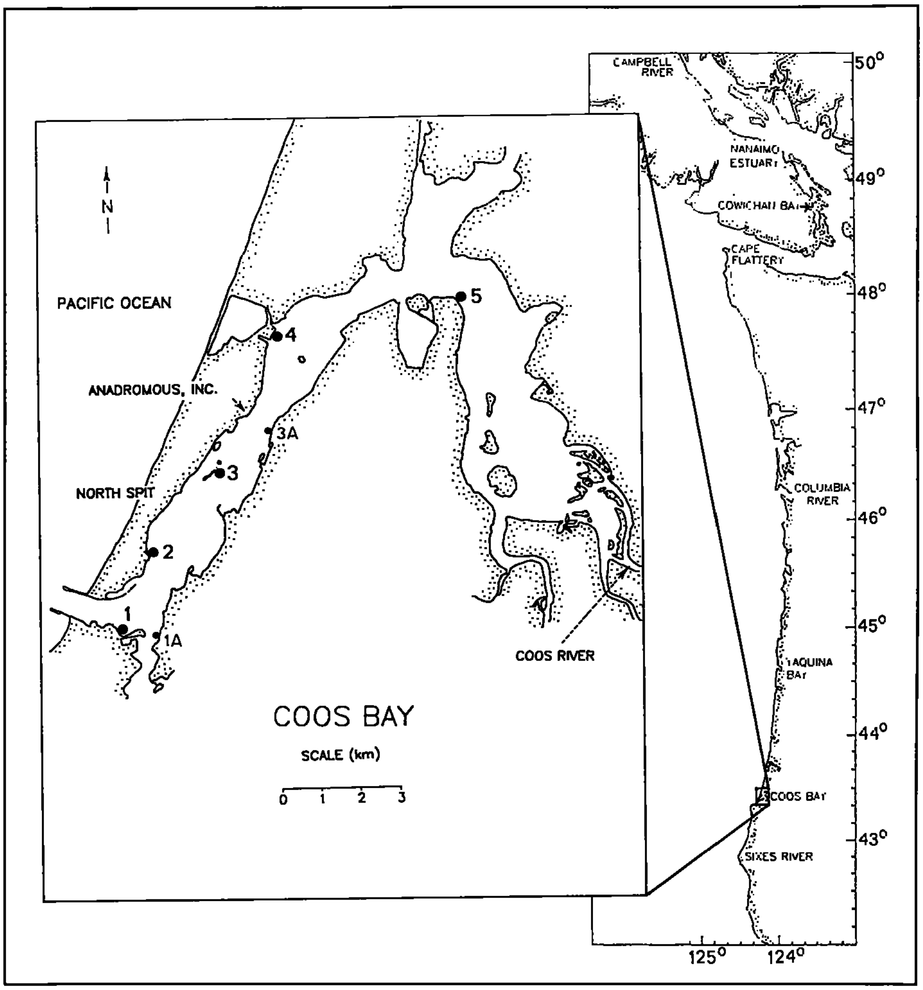

Figure 1
Coos Bay, Oregon, showing five stations routinely sampled and two sites occasionally sampled (1A and 3A) for juvenile chinook salmon with a beach seine in 1987. The Anadromous, Inc. release site on North Spit is indicated by an arrow. The Millacoma River (not shown) is a tributary of the Coos River. Also shown are other estuaries mentioned in the Discussion.

Generally, we sampled from the lower to the upper bay in the morning and in the opposite direction in the afternoon. Occasionally sets were made at two other sites (1A and 3A in Fig. 1).

The substrate at all stations was sand except at station 5 where it was gravel and mud. During low tide the seine usually sampled parts of eel grass beds at stations 2, 3, and 4.

About 415,000 subyearling fall chinook salmon were released in 1987 by the Salmon and Trout Enhancement Program (STEP) into tidewater tributaries of the Coos River between 27 and 35 km above station 5 (Fig. 1). These subyearling fall chinook salmon were released between 30 April and 28 June (half before and half after 23 May). Average fork length (FL) of fish at release ranged from approximately 48 to 94 mm (converted from mean weights, T. Rumreich and R. Bender, Oreg. Dep. Fish Wildl., P.O. Box 5430, Charleston, OR 97420, pers. commun., March 1988). Of STEP fall chinook salmon released in 1987, 74% were supposed to be fin-clipped. However, the actual percentage of fish with recognizable marks was not known because marking efficiency was not evaluated. Wild fall chinook salmon caught in the lower Millacoma and Coos Rivers were about the same size as STEP fish.

Over 5 million subyearling spring chinook salmon were released into Coos Bay in eight groups between 19 June and 1 October 1987 from Anadromous, Inc.'s holding and release facility located on North Spit (Fig. 1). These spring chinook salmon were considerably larger than the STEP or wild fall chinook salmon and averaged 123–156 mm FL at release. Between 0 and 5.9% (average 3.6%) of the fish in each group were coded-wire tagged (CWT) and had clipped adipose fins. We sampled the bay 1–2 days before and after each Anadromous, Inc. release and at about weekly intervals between releases.

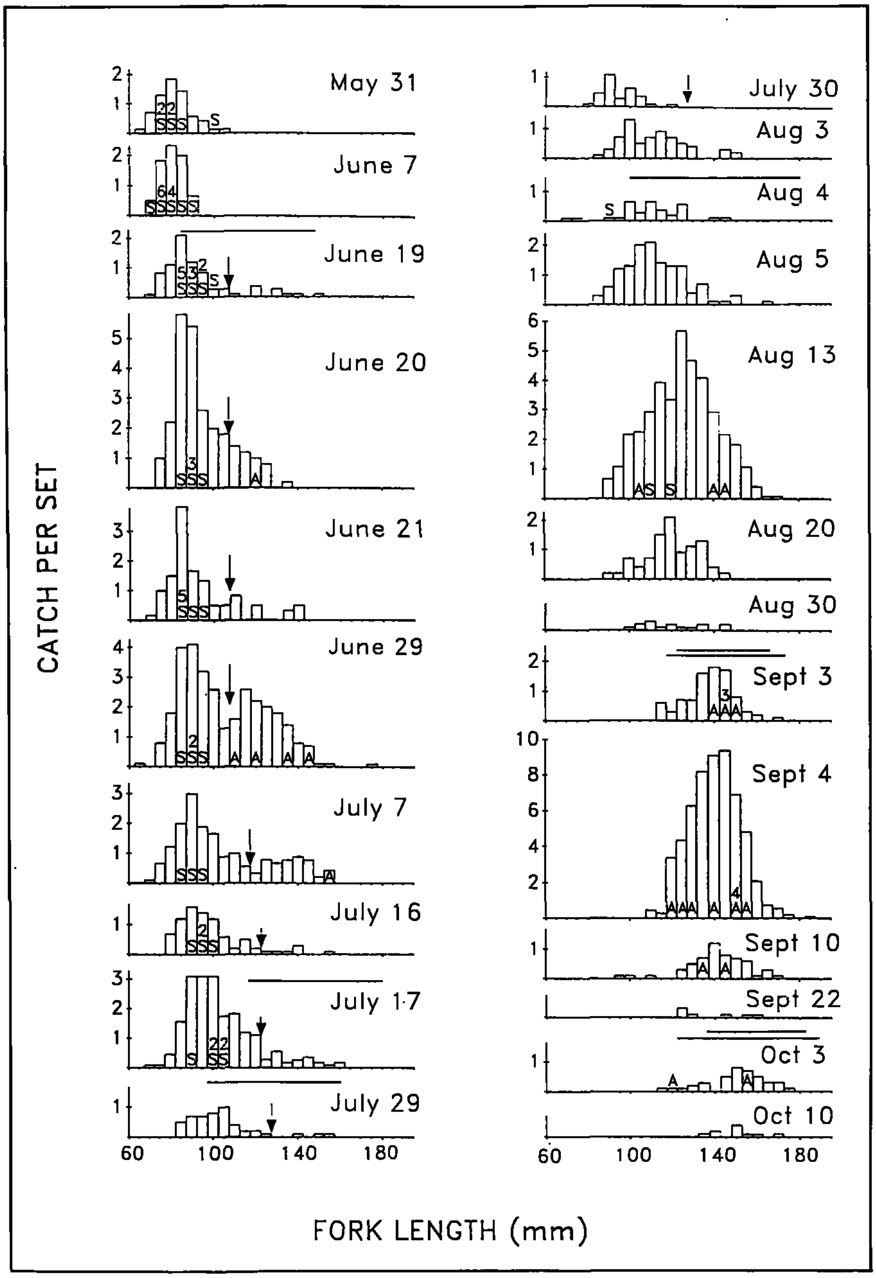

Figure 2
Length-frequency distributions of juvenile chinook salmon caught in Coos Bay, Oregon, in beach seines in 1987. Numbers of marked fall chinook salmon released by the Salmon and Trout Enhancement Program (S) and spring chinook salmon released from Anadromous, Inc. (A) caught in each length category are indicated. An "A" or "S" without a number represents a single fish. Heavy horizontal lines indicate lengths (±2 SD) of production groups of spring chinook salmon released by Anadromous, Inc. Arrows indicate the lengths used to separate fall and spring chinook.

Results

Immigration of fall chinook salmon

Juvenile wild and STEP fall chinook salmon were caught in the bay in large numbers starting in late May (Fig. 2). Only two juvenile chinook salmon were captured during our first two sampling trips on 25–26 April (8 sets) and 9 May (6 sets). Catches of juvenile wild and STEP fish in the lower reaches of the Millacoma and Coos Rivers entering the bay peaked on 15 May and 26 May, respectively, and declined to low levels after mid-June (R. Bender, Oreg. Dep. Fish Wildl., P.O. Box 5430, Charleston, OR 97420, pers. commun., March 1988).

Size-frequency distributions

Distinct modes in the length-frequency distribution of juvenile chinook salmon provided a basis for separating small STEP and wild fall chinook salmon from large Anadromous, Inc. chinook salmon until the end of July (Fig. 2). Recoveries of fin-clipped STEP fall chinook salmon (S in Figure 2) confirmed that the mode of small fish was mainly fall chinook salmon from 31 May through the end of July. Almost all fall chinook salmon captured before the first release of spring chinook salmon on 19 June were less than 105 mm FL. Although we caught some large spring chinook salmon after the first release on 19 June, a large, distinct mode of these fish was not apparent until 10 days later on 29 June. Recoveries of Anadromous, Inc. spring chinook salmon with CWTs (A in Figure 2) indicated that this second mode of large fish was mostly spring chinook salmon. This mode of large-sized fish was also obvious a week later on 7 July, but by 16 and 17 July catches of large fish had decreased to low levels. Catches of large chinook salmon did not increase immediately following the 17 and 29 July releases.

We classified fish as either fall or spring chinook salmon to estimate their relative abundances in the bay. On 19, 20, and 21 June fish that were ≤105 mm FL were considered fall chinook salmon and the larger fish were considered spring chinook salmon. (Arrows in Figure 2 indicate the division between these groups). On 29 June and 7 July, we used the valley between the two distinct modes to separate fall and spring chinook salmon. To account for growth of fish, we distinguished fall and spring chinook salmon at slightly larger lengths on 16, 17 July and 29, 30 July (120 and 125 mm FL, respectively). In August, length ranges of fall and spring chinook salmon overlapped and the two groups could not be separated by length. However, catch per set of fall chinook salmon on 29 and 30 July was lower than it had been in June and earlier in July, suggesting that abundance of fall chinook salmon probably peaked in June and July. Catches of fin-clipped fall chinook salmon (S in Figure 2) in August were also low compared with earlier periods. Therefore, we assumed that subsequent increases in catch per set of juvenile chinook salmon in August (Fig. 2) were due almost exclusively to releases of large spring chinook salmon from Anadromous, Inc. In the following discussion we have treated all fish caught starting 3 August as spring chinook salmon, realizing that this probably overestimates the abundance of spring chinook salmon in the bay, especially in early August when a few marked fall chinook salmon were caught.

The proportions of adipose clipped or CWT fish in our catches of spring chinook salmon were usually similar to the proportions of CWT fish in the immediately preceding releases of spring chinook salmon from Anadromous, Inc. (χ^2 tests, $p>0.05$) (Table 1). This supports the conclusion that most fish we classified as spring chinook salmon originated from the Anadromous, Inc. facility. An exception was during the period 4–30 August when the proportion of CWT fish in our catch of spring chinook salmon was significantly lower than the proportion released by Anadromous, Inc. on 4 August ($\chi^2=6.14$, $p<0.025$). This result may be explained by lack of complete mixing of marked and unmarked Anadromous, Inc. fish and their patchy distribution. Over 77% of the catch in August occurred in just five sets, three of which were on the same day. Large numbers of fall chinook salmon in the bay in August mistakenly classified as spring chinook salmon also could have produced the low proportion of CWT fish. However, there is little direct evidence that fall chinook salmon were abundant in the bay during August since very few fin-clipped fish were recovered, although regeneration of fins may have made recognition of marks difficult (R. Bender, Oreg. Dep. Fish Wildl., P.O. Box 5430, Charleston, OR 97420, pers. commun., March 1988).

Table 1
Percentage of coded-wire tagged (CWT) or adipose-clipped fish in the catch of spring chinook salmon from Coos Bay, Oregon, vs. the percentage of CWT fish in the preceding release from Anadromous, Inc.

	Catch		Anadromous, Inc.	
Period	n	% CWT[a]	% CWT in release	χ^2
6/19–7/7	232	2.6	2.3	0.08
7/17–8/3	92	1.1	2.5	0.75
8/4–8/30	751	0.7	1.9	6.14[b]
9/3–9/22	775	2.3	2.9	0.93
10/3–10/10	50	4.0	5.9	0.32

[a] Includes 16 Anadromous, Inc. CWT fish, 11 fish with unreadable CWTs probably from Anadromous Inc., and 5 adipose-clipped fish without tags.
[b] Observed frequency of tags is significantly different from expected frequency, $p<0.025$.

Catch distribution

Before mid-June, roughly equal numbers of fall chinook salmon were caught at each of the five standard stations (Fig. 3). After mid-June, fall chinook salmon were concentrated near the mouth of the bay at station 1, although they were also caught at the other stations. At station 1, catch per set of fall chinook salmon peaked in June and July and dropped to low levels at the end of July (Fig. 3).

Catches of Anadromous, Inc. spring chinook salmon were extremely patchy, with large catches at one or two stations and low catches at the others. After the first release on 19 June, almost all spring chinook salmon were found upbay at station 5, but later releases were caught at the lower bay stations 1, 1A (not shown), and 2 (Fig. 3). Catch per set of spring chinook

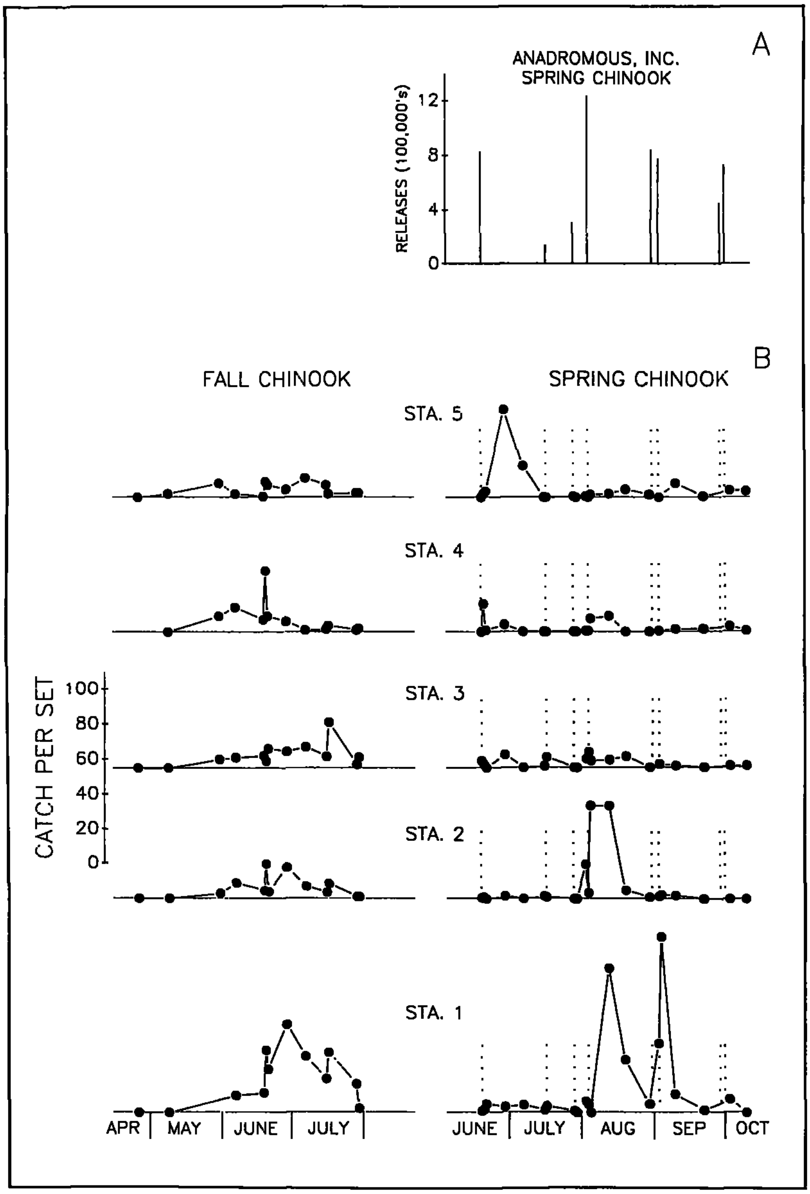

Figure 3

(A) Numbers of spring chinook salmon released in 1987 into Coos Bay, Oregon, by Anadromous, Inc. (B) Mean catch per set of fall and spring chinook salmon by station. Dotted lines indicate release dates.

salmon peaked 10 days, 1–9 days and 1–4 days following the 19 June, 4 August, and 31 August–3 September releases, respectively, and generally fell to low levels in the inter-release periods. Little increase in catch per set followed the 29 September and 1 October releases.

In general, the distribution in the bay of marked fall and spring chinook salmon was consistent with the distribution of unmarked fish. Mean catch per set of fin-clipped fall chinook salmon was much greater at lower bay stations 1 and 1A than at any other stations (Table 2). On average, all fin-clipped fish were caught at station 1 about 13 days later than at upbay stations 4 and 5 (Table 2), suggesting a gradual movement of fish downbay. However, among individual mark groups the trend for later capture in the lower bay than in the upper bay was clear only for right-pelvic clipped fish. Most (4 of 6) CWT fish from the 19 June release of spring chinook salmon were caught upbay at station 5, and none were caught downbay at stations 1 or 2. In contrast, after the 4 August release, one CWT fish was found at each of stations 1, 2, and 3, and, after the 31 August release, 15 of 16 CWT fish were recovered downbay at station 1.

Juvenile spring chinook salmon were found in large aggregations (67% of the total catch occurred in 5% of the sets) while STEP and wild fall chinook salmon were more evenly dispersed. Spring chinook salmon were present in only 60% of sets after the first release, whereas fall chinook salmon occurred in 95% of sets between 9 May and 30 July.

Table 2
Mean catch per set (CPUE) of fin-clipped fall chinook salmon and mean days between release and recovery at each site in Coos Bay, Oregon, for each of four mark groups.

Station	No. sets (5/9–8/13)	Fin-clipped fish recovered	Mean CPUE	Mean days between release and recovery*				
				RP_2	An	Dor	LP_2	All combined
Upbay								
5	29	8	0.27	1	38	35	18	19
4	28	6	0.21	21				21
3	28	3	0.11	23	30			29
3A	3	1	0.33	23				23
2	28	9	0.32	26	23			25
1	27	34	1.25	37	30	23	18	33
1A	1	2	2.00		83		46	65
Downbay								

*Mean days = $\Sigma(\text{CPUE}(d) \cdot d)/\Sigma \text{CPUE}(d)$, where CPUE(d) = number tags recovered/number of sets on day following release = d.
RP_2 = right pelvic, An = anal, Dor = dorsal, and LP_2 = left pelvic clip

No consistent relationship was found between water temperature and catch of juvenile chinook salmon. Temperatures measured on the bottom at about 0.3 m depth generally changed little between May and October but increased with distance from the mouth of the bay, averaging 12.3, 11.9, 13.8, 15.0, and 16.8°C at stations 1–5, respectively, for all sampling dates combined. The large catches of juvenile spring chinook salmon at stations 1 and 2 and of juvenile fall chinook salmon at station 1 (Fig. 3) occurred at water temperatures between 9–14°C. However, large catches of spring chinook salmon also occurred at station 5 in June and July at temperatures above 17°C. Surface salinity was high at all stations during the study period (usually >29‰ after mid-June), indicating little influence of freshwater at our sampling sites. (See also Burt and McAlister 1959.)

Residence in the bay

Unmarked STEP or wild fall chinook salmon resided in the shallow nearshore areas of the bay for about 1–2 months. Catch per set of fall chinook salmon was highest between 20 June and 17 July (Fig. 3), about 1.0–1.5 months later than the peak catches in the river systems just above the bay (R. Bender, Oreg. Dep. Fish Wildl., P.O. Box 5430, Charleston, OR 97420, pers. commun., March 1988).

Mean duration of residence in the bay of 63 fin-clipped STEP fall chinook salmon was about 1 month (Table 2). The average number of days (weighted by catch per set of the marked fish) between release of the median fish in a mark group and recovery in the bay of fish from that same mark group was 29 days (n=63, range −6 to 83 days). Eight fin-clipped fish were caught more than 50 days after release. The number of days between release of the last fish in a mark-group and the recovery in the bay of fish from that same mark-group, a minimal estimate of time since release, averaged 24 days (n=63, range −13 to 81 days). Average recovery date of right-pelvic and anal fin-clipped fish was 27 and 32 days, respectively, after release of the median fish (Table 2).

Peak catch per set of spring chinook salmon usually occurred within 1–10 days after Anadromous, Inc. releases, and catches declined rapidly afterwards, suggesting that spring chinook salmon had a much shorter period of residence in shallow waters of the bay than fall chinook salmon (Fig. 3). Catches returned to low levels within about 25 days following the releases on 19 June and 29 July–4 August and within 7–10 days following the releases on 31 August and 3 September. The very rapid decline in catch per set after the 31 August and 3 September releases, together with the low catches of fish from the last two releases on 29 September and 1 October, indicate that movement into deepwater channels or out of the bay for these late summer releases may have been more rapid than for earlier releases.

All but one of the 27 CWT Anadromous, Inc. spring chinook salmon caught in beach seines were captured 10 or fewer days after release* (range 1–18 days);

*Tags from eleven of these fish were unreadable; however, these unreadable tags were probably from the 31 Aug. and 1 Oct. releases (Mary McGowan, Anadromous, Inc., P.O. Box 1007, North Bend, OR 97459, pers. commun., Jan. 1989).

another indication that residence of spring chinook salmon in the bay is relatively short. Moreover, CWT spring chinook salmon from each release were recovered only during the period before the next release.

Growth rates

Growth rates of anal and right-pelvic clipped fall chinook salmon, estimated from the slopes of the linear regressions of fork length on days since release of the median fish, were 0.54 mm/day ($n = 19$, $r^2 = 0.74$) and 0.29 mm/day ($n = 33$, $r^2 = 0.33$), respectively. Because emigration from the bay may be positively related to fish size, these observed growth rates probably underestimate the true average rates of growth of fish in the mark groups.

Discussion

Our data indicate that small fall chinook salmon reside in Coos Bay for a longer period than do larger spring chinook salmon. Duration of residence in estuaries may be related to the size or stock of fish. Dawley et al. (1986) found that rates of downstream movement of subyearling chinook salmon from lower Columbia River stocks were positively related to fish length. Movement of small subyearling fish through the Columbia River estuary decreased by 30% relative to movement rates farther upstream, while larger yearling fish moved through the estuary at the same rate as through the river. Neither subyearling nor yearling fish, however, reared for long periods in the Columbia River estuary.

Because our collections were made by beach seine in shallow nearshore areas of Coos Bay, we can say little about the utilization of deeper channel areas by juvenile fall and spring chinook salmon. We do not know whether peak abundances of fall or spring chinook salmon in channels coincide with peak abundances in shallow areas. Neither do we know what fraction of fall or spring chinook salmon at any given time are in shallow or channel areas. Temporal and size-related differences in utilization of nearshore and channel areas by juvenile chinook salmon have been found in other estuaries and also may occur in Coos Bay. (See Figure 1 for locations of other estuaries discussed.) In Yaquina Bay, Myers (1980) found that although catches in shallow areas peaked in late July and early August, catches continued to increase in channels into October. In both Yaquina Bay and the Columbia River estuary, small fish and large fish preferentially utilized nearshore and channel areas, respectively. The mean lengths of wild juvenile chinook salmon in beach seine (nearshore) and lampara net (channel) catches in Yaquina Bay during June were 88 and 106 mm FL, respectively (Myers 1980). In the upper Columbia River estuary, many more yearling chinook salmon (large fish) were caught in channels than in nearshore areas and, conversely, more subyearling chinook salmon (smaller fish) were found in nearshore areas than in channels (Dawley et al. 1986). In addition, subyearling fall chinook salmon caught in nearshore areas were 10–20 mm shorter than those caught in channel areas, and catch rates of subyearling chinook salmon in nearshore areas were inversely related to length (Dawley et al. 1986). If similar size-related distributional patterns occur in Coos Bay, then the large spring chinook salmon released from Anadromous, Inc. may utilize channel areas much more extensively than shallow nearshore areas.

Delays of up to 10 days occurred between releases of spring chinook salmon from the Anadromous, Inc. facility and peak catches of juvenile spring chinook salmon in nearby (<8 km distant) shallow areas (Figs. 2 and 3). This suggests that spring chinook salmon may stay in channels for several days following release and then disperse into shallow waters. Some of the spring chinook salmon occurring at stations 1 and 2 near the mouth of the bay, especially those found several days after a release, may even have reentered the shallows from the ocean. Two CWT juvenile chinook salmon released earlier in 1987 in Yaquina Bay were found later in Coos Bay at station 1. This demonstrates that juvenile chinook salmon, after they have entered the ocean, sometimes reenter estuaries.

The apparent rates of growth in length for two groups of fin-clipped STEP fall chinook salmon caught in Coos Bay (0.29 and 0.54 mm/day) were similar to rates reported for a group of marked subyearling fish caught in the upper Columbia River estuary (Dawley et al. 1986; 0.60 mm/day) and reported by Levings et al. (1986) for fry caught in the Campbell River estuary (0.46–0.70 mm/day) but lower than reported by Healey (1980) for fry in Nanaimo Estuary (1.32 mm/day) or by Argue et al. (1986) for smolts in Cowichan Bay (0.97 mm/day). All these calculations of growth rates were based on changes in length of marked fish with time and should have a similar bias (i.e., possible faster emigration of fast-growing or large fish that results in underestimates of actual mean growth rates attained in the bay). Reimers (1973) reported little change in size of marked and unmarked fish in the Sixes estuary June through August, after which growth rates increased dramatically. He attributed the slow growth of juvenile fish during the June–August period to their high densities in the bay. Myers (1980) found substantial increases in size of wild chinook salmon with time and between the upper and lower bay, indicating substantial growth of wild chinook salmon. Thus growth of juvenile chinook salmon appears to vary among estuaries, perhaps depending on their density and food supply.

An interesting feature of the catch distribution of fall and spring chinook salmon in Coos Bay (Fig. 3) is that when the catch of fall chinook salmon was highest at the downbay station 1 (20 June–29 July), the catch of spring chinook salmon at this station was low. Conversely, when the catch of spring chinook salmon was high at the upbay station 5 (29 June–7 July), the catch of fall chinook salmon at this station was relatively low. Later in the summer when most spring chinook salmon were released, fewer fall chinook salmon were caught in the bay. Apparently peak abundances of juvenile fall and spring chinook salmon differed in time and place. The potential for competition between these two stocks was probably greatest in June and July after the large release of spring chinook salmon and when large numbers of fall chinook salmon were present in shallow nearshore areas of the bay. However, since the two groups were found at different sites, direct competition may have been limited.

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