Use of Hatchery Coho Salmon (*Oncorhynchus kisutch*) Presmolts to Rebuild Wild Populations in Oregon Coastal Streams

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We evaluated the effectiveness of using hatchery coho salmon (*Oncorhynchus kisutch*) presmolts to rebuild wild populations in Oregon coastal streams. Juvenile and adult populations were monitored in 15 stocked and 15 unstocked streams from summer 1980 until summer 1985. During the summers following the planting of presmolts, the number of juveniles per square metre of pool surface area was higher in the stocked streams than in the unstocked streams. However, wild juveniles were significantly less abundant in the stocked streams during the 2 yr when density of wild juveniles was estimated separately from hatchery juveniles. Adult returns to the stocked streams were not significantly different from adult returns to the unstocked streams, but returns tended to be earlier in the stocked streams than in the unstocked streams. Despite similar numbers of adults per kilometre in the stocked streams and unstocked streams in the years the presmolts returned to spawn, the resulting densities of juveniles in the stocked streams were significantly lower than the densities of juveniles in the unstocked streams. We concluded that the early time of spawning of the hatchery coho salmon was largely responsible for their failure to rebuild the populations in the streams stocked with presmolts.

Les auteurs ont évalué l'efficacité de l'utilisation de pré-smolts de saumon coho (*Oncorhynchus kisutch*) d'élevage pour le rétablissement des populations sauvages de cours d'eau côtiers de l'Oregon. Des populations de juvéniles et d'adultes de 15 cours d'eau empoissonnés et de 15 cours d'eau non empoissonnés ont été contrôlées de l'été 1980 à l'été 1985. Au cours des étés suivant le peuplement par pré-smolts, la concentration de juvéniles par mètre carré de surface de fosse était plus élevée dans les cours d'eau empoissonnés. Les juvéniles sauvages étaient cependant significativement moins abondants dans les cours d'eau empoissonnés au cours des 2 ans où la densité des juvéniles sauvages a été estimée séparément de celle des juvéniles d'élevage. Les remontées d'adultes vers les cours d'eau empoissonnés ne différaient pas de façon appréciable de celles des autres cours d'eau, mais avaient tendance à être plus hâtives. En dépit de concentrations similaires d'adultes (nombre par kilometre) dans les deux types de cours d'eau les années où les pré-smolts retournaient frayer, les densités de juvéniles dans les cours d'eau empoissonnés étaient significativement inférieures à celles des cours d'eau non empoissonnés. Les auteurs concluent que la fraie hâtive des saumons cohos d'élevage explique en grande partie leur incapacité à rétablir les populations dans les cours d'eau empoissonnés de pré-smolts.

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The abundance of wild coho salmon (*Oncorhynchus kisutch*) in Oregon coastal streams has declined greatly since the mid-1960s (Oregon Department of Fish and Wildlife (ODFW) 1982). As a result, ocean fisheries for coho salmon have been severely restricted (Pacific Fisheries Management Council (PFMC) 1984). One by-product of the restricted fisheries has been the return of more adults to Oregon hatcheries than are needed to fill quotas for smolt production.

In response to the problem of abundant hatchery and scarce wild coho salmon, the ODFW began a restoration program to rebuild populations of wild coho salmon. The release of offspring of surplus hatchery spawners into coastal streams as unfed fry or as fed fingerlings (presmolts) has been a major component of this program. During the first 3 yr of the program (1980–82), approximately 3.4 million unfed fry and 14 million presmolts were released into coastal streams. The Alsea River, Siletz River, and Trask River stocks of hatchery coho were used in the program. Because they have been in the hatcheries for many generations, these stocks typically spawn much earlier than wild coho in Oregon coastal rivers.

Although hatchery steelhead (*Salmo gairdneri*) may not survive as well in the wild as wild steelhead (Reisenbichler and McIntyre 1977; Chilcote et al. 1984), similar data are not available for coho salmon. In our study, presmolt hatchery coho salmon were released in an attempt to rebuild populations of wild coho salmon. The objectives were to determine if the release of hatchery presmolts resulted in (1) higher densities of juveniles in the stocked streams in the year of release, (2) more spawners in the stocked streams upon their return 3 yr hence, (3) higher densities of juveniles in the next generation, and (4) undesirable effects on populations of wild coho salmon.

Methods

Study Streams

Fifteen study streams were selected from the approximately 100 coastal streams that were stocked with hatchery coho pre-

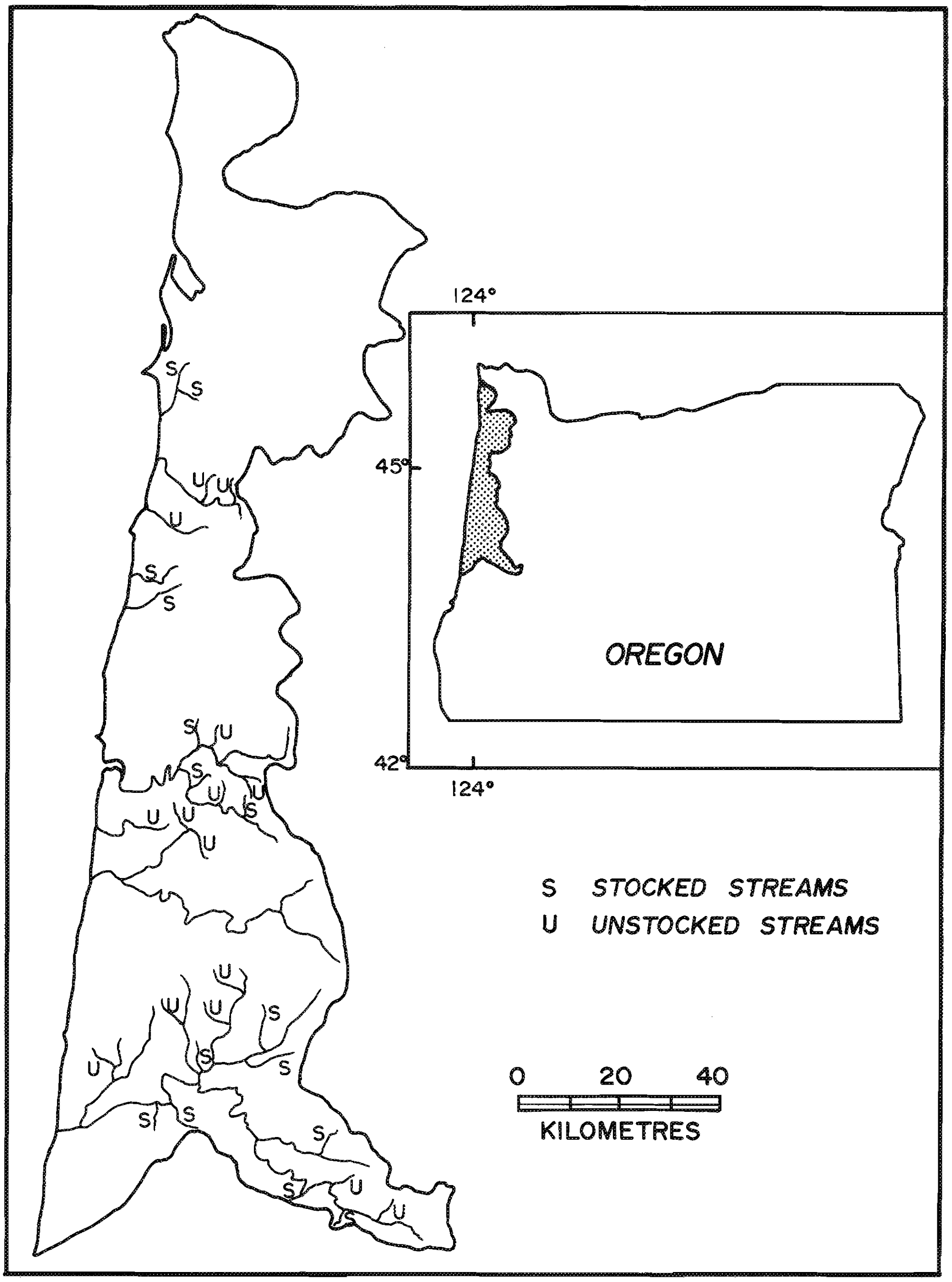

FIG. 1. Location of the presmolt evaluation study streams relative to the geographical distribution of the coho presmolt releases (shaded area).

smolts in 1980. An additional 15 unstocked streams were selected as controls. The 30 streams were distributed over nine Oregon coastal basins (Fig. 1).

The hatchery presmolts were planted during April and May of 1980–82. Presmolts averaged 2.25 g (62 mm) and were stocked in the accessible portion of each stream at an average density of $3.9/m^2$ of expected summer surface area. Known numbers of presmolts marked with a clipped adipose fin and a coded-wire-tag were released in 11 streams in 1981 and in 15 streams in 1982. The populations in the stocked and unstocked streams were sampled each summer from 1980 to 1985 as juveniles (6 yr) and each fall and winter from 1980–81 to 1984–85 as adult spawners (5 yr).

Adult Density

The evaluation was designed to determine whether stocking resulted in a change in the average spawner density in run years 1982–84 from the average spawner density in run years 1980–81 (Table 1). Run years begin in October of the year indicated and end the following March. Spawner density in the unstocked streams was monitored to account for trends that were unrelated to the stocking, such as changing harvest rates.

Spawning surveys of live adult coho salmon were conducted by walking index reaches of each study stream approximately weekly from mid-October until mid-February (except in 1984–85 when low flows extended the spawning season to mid-March). Surveys were only conducted under conditions of

TABLE 1. Summary of the hypotheses. The data used to test each hypothesis are identified by number (H_1—H_4). Population components are listed as wild (W), hatchery (H), or hatchery offspring (HO).

Hypotheses

H_1: no difference in the average density of juveniles between the stocked and unstocked streams during the summers following stocking
H_2: no difference in the average density of wild juveniles between the stocked and unstocked streams following release of the presmolts
H_3: no differences between the average numbers of early, late, and total spawners between the stocked and unstocked streams during the years that the hatchery fish returned
H_4: no difference in the average density of juveniles between the stocked and unstocked streams during the summers following return of the hatchery fish

Adult run year	Population components: Stocked streams	Population components: Unstocked streams	Summer of juvenile sampling	Population components: Stocked streams	Population components: Unstocked streams
				H_1	
1979	W	W	1980	H + W	W
				H_2	
1980	W	W	1981	H + W	W
1981	W	W	1982	H + W	W
	H_3			H_4	
1982	H + W	W	1983	HO + W	W
1983	H + W	W	1984	HO + W	W
1984	H + W	W	1985	HO + W	W

good water clarity. This method has been shown to account for an average of 75.5 ± 1.4% of the adult coho present in index reaches of Oregon coastal streams (Solazzi 1984). Index reaches totaled 25.1 km in the stocked streams and 25.0 km in the unstocked streams. We made an area-under-the-curve (AUC) estimate of spawners (Beidler and Nickelson 1980; Neilson and Geen 1981) for each study stream. By this method, total spawners in an index reach were estimated by dividing AUC-estimated fish-days by an average residence time of 11.3 d/fish (the average of the values reported by Willis (1954) and Beidler and Nickelson (1980)). The estimated number of spawners was then divided by the length of stream surveyed to express density as spawners per kilometre.

We tested the hypothesis of no difference in average spawner density between the stocked streams and the unstocked streams for run years 1982–84 (poststocking period) by using analysis of covariance, with average spawner density in each stream in run years 1980–81 (prestocking period) as the covariate. This allowed us to account for any differences between the stocked and unstocked streams that existed prior to stocking (Anderson et al. 1980). We believe that the assumption that the covariable be measured without error is met because of the small amount of error in our estimates. We tested the same hypothesis for early spawners and for late spawners (fish counted before December 1 and after November 30, respectively). December 1 was chosen because in almost all years, spawning at Fall Creek Hatchery (Alsea River) is completed before this date (ODFW, unpubl. data) and thus the vast majority of fish counted in the stocked streams after December 1 would be of wild origin.

Juvenile Density

The evaluation was designed to determine if juvenile densities changed because of the release of hatchery presmolts and to determine if any differences were retained in the next generation. We tested the hypotheses that there was no difference in juvenile density between the stocked and unstocked streams in each period (1980–82 and 1983–85) (Table 1).

In each stream, 15 study reaches were chosen by selecting three units of five consecutive pools. In the stocked streams, the units were located at points 20, 50, and 80% of the distance from the mouth to the uppermost stocking site. In the unstocked streams, the units were located at points 20, 50, and 80% of the distance from the mouth to the upper limits of coho distribution. The surface area of each pool and the riffle immediately upstream were measured and the juvenile population was estimated by the removal method (Seber and LeCren 1967). Populations consisted almost exclusively of age 0 coho because coho in Oregon typically smolt after 1 yr in freshwater. All population estimates and all pool surface areas were summed for each stream and the population density for each stream was expressed as fish per square metre of pool because coho were almost never found in the riffles.

We tested the hypotheses of no difference in average density of juvenile coho salmon between stocked and unstocked streams for the years 1980–82 (presmolt stocking years) using

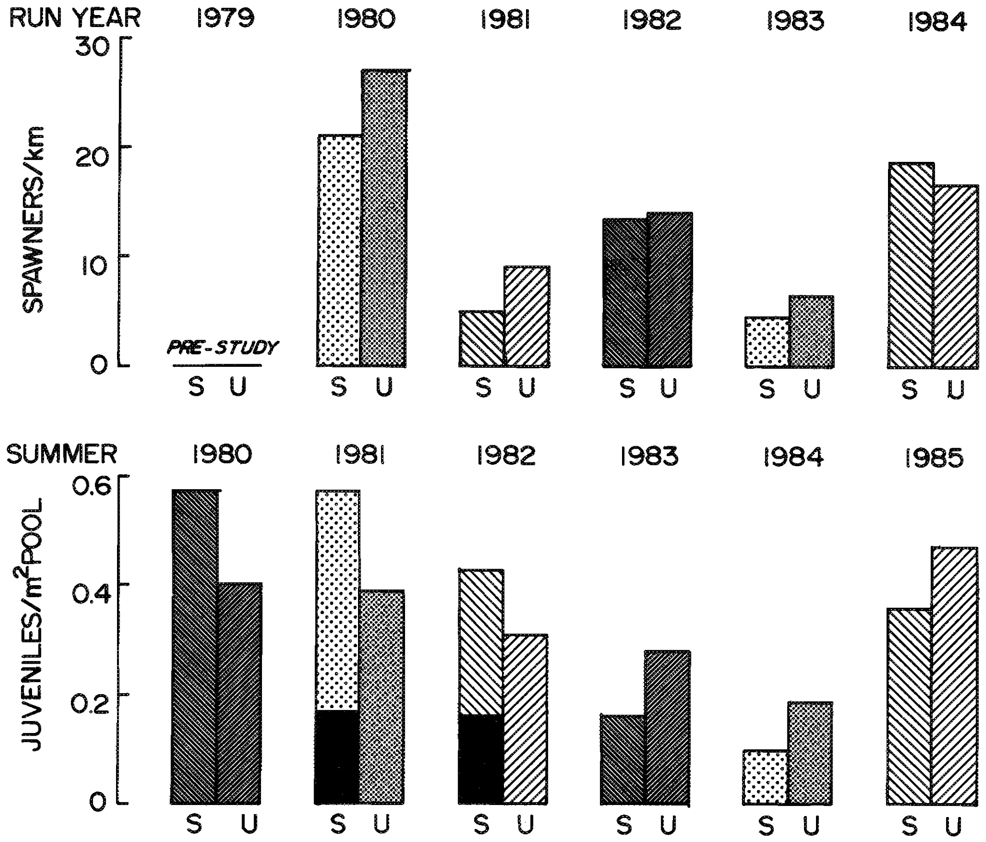

FIG. 2. Average density of adult and juvenile coho salmon in stocked (S) and unstocked (U) streams. Streams were stocked with hatchery presmolts in springs 1980–82. Similar shading represents the brood cycle. Solid portions of juvenile bars for stocked streams in 1981 and 1982 designate wild juveniles.

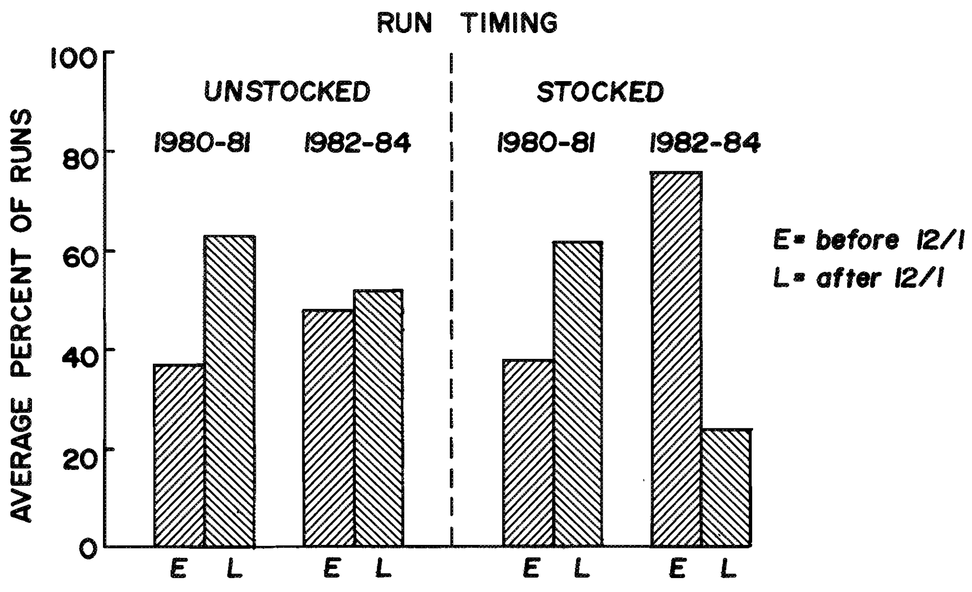

FIG. 3. Comparison of the proportion of early (E) and late (L) spawners (before and after December 1) in the stocked and unstocked streams for 1980 and 1981 (the prestocking period) and for 1982–84 (the poststocking period).

a two-tailed *t*-test. We used analysis of covariance, with spawner density as the covariate, to test the same hypothesis for the years 1983–85 (presmolt offspring years). This allowed us to account for any differences that might exist in spawner density between the stocked and unstocked streams.

Interaction Between Hatchery and Wild Juveniles

We had no direct measure of the density of wild juveniles in the stocked streams prior to stocking because the hatchery presmolts were stocked at a time when wild juveniles were still emerging from the gravel. Therefore, we used an indirect ap-

TABLE 2. Average densities of juvenile coho salmon (fish/m^2 of pool) in 15 stocked and 15 unstocked streams, 1980–85. Standard deviations are in parentheses. Adjusted values are adjusted for differences in spawner density between streams.

Group	Treatment: Stocked	Unstocked	P
1980–82 total juveniles	0.52 (0.21)	0.37 (0.18)	0.036
1981–82 wild juveniles	0.18 (0.14)	0.35 (0.16)	
Adjusted	0.19	0.34	0.010
1983–85 wild juveniles	0.21 (0.11)	0.31 (0.17)	
Adjusted	0.21	0.31	0.045

proach to determine the impacts of planting hatchery presmolts on the wild populations. Because the study streams were chosen randomly and the stocked and unstocked streams were geographically interspersed (Fig. 1), we assumed that the number of juveniles produced per spawner was similar for the stocked and unstocked streams. Then, for a given number of wild spawners, we would expect to find the same average density of wild juveniles in the stocked streams as we found in the unstocked streams if no effects of hatchery presmolts on wild juveniles had occurred.

We estimated the number of wild juveniles in stocked streams containing marked presmolts by subtracting the estimated number of hatchery coho salmon in each reach from the population estimate for that reach. The number of hatchery coho salmon in each reach was estimated (H) using the following equation:

$$H = (n/p)(N/c)$$

where n = the number of marked coho salmon captured, p = the proportion of marked coho salmon stocked, N = the total population estimate, and c = the total number of coho salmon captured (marked and unmarked). Estimates of the wild populations were summed and the density of wild juveniles for each stream was expressed as fish per square metre of pool.

We tested the hypothesis that there was no difference in average density of wild juveniles between the stocked and unstocked streams in 1981 and 1982 (Table 1) by using analysis of covariance, with spawner density as the covariate. This allowed us to account for any differences that might exist in spawner density between the stocked and unstocked streams.

Results

During the summers following planting of hatchery coho salmon presmolts (1980–82), average density of all juveniles in the stocked streams was 41% higher (P = 0.018) than the average density of juveniles in the unstocked streams (Fig. 2; Table 2). However, after adjusting for differences in spawner density, the average density of juvenile wild coho salmon in the stocked streams in 1981 and 1982 was 44% lower (P = 0.010) than the average density of juvenile wild coho salmon in the unstocked streams in 1981 and 1982 (Table 2).

After adjusting for differences in adult density among streams in the prestocking period, there was no difference (P = 0.642) in average density of spawners between the stocked and unstocked streams in the years the presmolts returned as adults (Fig. 2; Table 3). Whereas spawner density in the poststocking period was not different between the stocked and unstocked streams, there was a large shift from late spawners to early spawners in the stocked streams (Fig. 3). After adjusting for differences in density of early and late spawners among streams in the prestocking period, the average densities of early and late spawners in the stocked streams during the poststocking period were 70% higher (P = 0.73) and 48% lower (P = 0.035), respectively, than the average densities of early and late spawners in the unstocked streams (Table 3).

TABLE 3. Average density (adults/km) of early (before December 1), late (after November 30), and total coho spawners in 15 stocked and 15 unstocked streams. Standard deviation is in parentheses. Adjusted values are adjusted for prestocking differences in spawning density between streams.

Period	Treatment: Stocked	Unstocked	P
Prestocking (1980–81)			
Early	4.8 (6.7)	6.5 (7.9)	
Late	8.0 (7.6)	11.3 (9.5)	
Total	12.8 (13.7)	17.8 (16.5)	
Poststocking (1982–84)			
Early	9.4 (7.6)	6.0 (4.7)	
Adjusted	9.7	5.6	0.072
Late	3.0 (1.9)	6.4 (4.8)	
Adjusted	3.2	6.1	0.035
Total	12.3 (8.2)	12.3 (8.1)	
Adjusted	13.0	11.7	0.642

Although total spawner density in the 1982–84 runs (the years that the presmolts returned) was not different between the stocked and unstocked streams, density of juveniles in the stocked streams the following summer averaged 32% lower (P = 0.045) than the density of juveniles in the unstocked streams (Fig. 2; Table 2).

Discussion

The release of hatchery coho salmon presmolts during late spring increased by 41% the overall density of juveniles rearing in the stocked streams during the summer following release. In six tributaries stocked with hatchery coho presmolts in the Clearwater River basin of Washington, the summer densities of juveniles were 200–300% higher than the summer densities of juveniles in unstocked tributaries during the preceding 2 yr (S. B. Mathews, University of Washington, Seattle, WA, pers. comm.). However, in our study, 44% of the wild juveniles in the stocked streams were replaced by hatchery presmolts. We believe this replacement was the result of competition between smaller wild coho and the larger hatchery coho. The hatchery presmolts were released at an average length of about 62 mm at a time when newly emerged wild juveniles would have been about 39 mm in length (Moring and Lantz 1975). This size advantage for the hatchery presmolts was due to an earlier spawning time and to 2 or 3 mo of feeding in the hatchery. Chapman (1962) and Mason (1966) found that for wild coho salmon, larger individuals dominated smaller individuals causing their emigration or death.

On the average, density of spawners in the stocked streams was not statistically different as a result of the release of hatchery presmolts. Whereas a few individual streams did experience substantial increases, most did not. Because of the large amount of variation in spawning density among streams, the average for the stocked streams would have had to have been 56% greater than the average for the unstocked streams for us

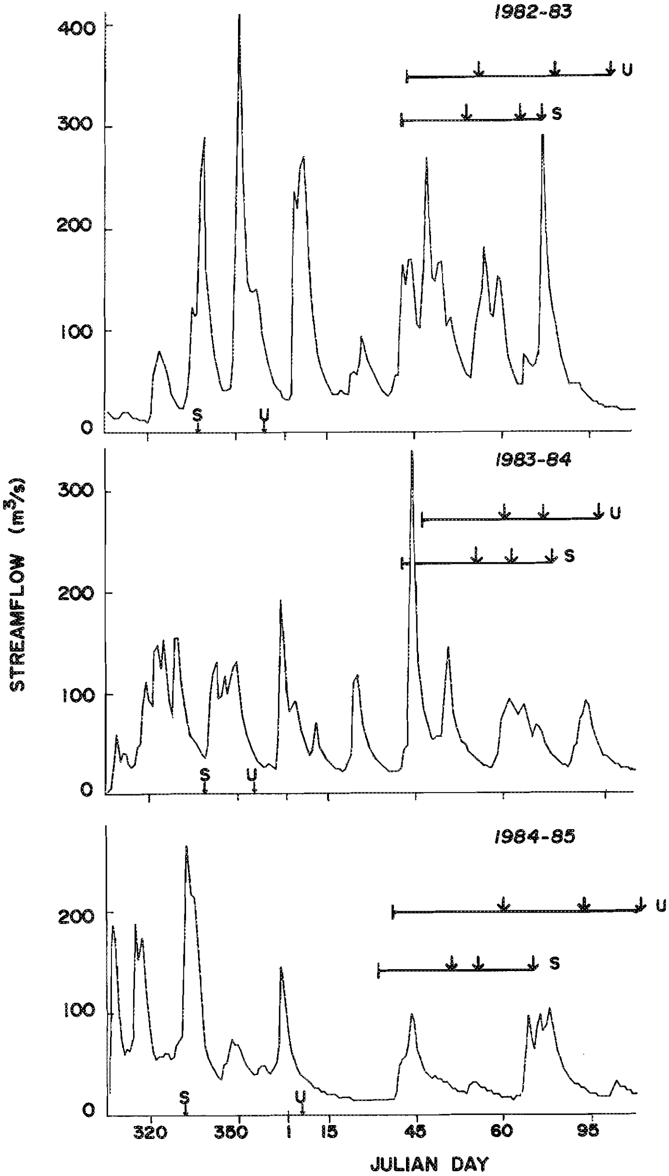

FIG. 4. Average daily streamflow for the Nestucca, Siletz, Yaquina, Alsea, and Siuslaw river basins, November through April. The arrows on the horizontal axis designate the time at which 75% of the spawners had been observed in the stocked (S) and in the unstocked (U) study streams. The estimated period from beginning until 75% emergence is shown by the horizontal lines labeled S and U. The arrows represent the completion of 25, 50 and 75% of emergence.

to detect a difference at the 90% level of significance, 80% of the time. The average density of spawners in the unstocked streams declined during the poststocking period compared with the prestocking period because of reduced survival and increased rate of harvest of adults returning in run year 1983 (Fig. 2), the result of El Niño (Johnson 1984). The average density in the stocked streams during the poststocking period was about the same as during the prestocking period despite the poor returns in 1983. This result suggests that the stocking of presmolts probably had a net positive effect on number of spawners, but that our tests were not sensitive enough to detect it statistically.

The density of late spawners in the stocked streams during the poststocking period was 48% less than the density of late spawners in the unstocked streams, probably the result of the decrease in wild juveniles of the same broods in the stocked streams. When combined with a 70% greater occurrence of early spawners in the stocked streams due to the return of hatchery adults, this resulted in the average time of spawning in the stocked streams during the poststocking period being about 2.5 wk earlier than the average time of spawning in the unstocked streams.

We believe that the reduced density of juvenile coho salmon in the stocked streams compared with the density of juvenile coho salmon in the unstocked streams during the summers following the 1982–84 spawning runs was related to the shift in the time of spawning in the stocked streams. We believe that the early spawners contributed very little to juvenile recruitment because juvenile abundance in the 30 study streams during 1983–85 was correlated with density of late spawners ($P < 0.001$) but not with density of total spawners ($P = 0.350$). Streamflow conditions during the periods following spawning and following emergence could explain the poor contribution of the early spawners. The shift toward an earlier time of spawning and the reduction in absolute numbers of late spawners translated into an earlier period of emergence for the stocked streams compared with the unstocked streams. Hartman et al. (1982) speculated that earlier emergence of coho salmon fry in Carnation Creek, British Columbia, resulted in greater emigration of the fry because of the increased occurrence of freshets early in the year. Cramer et al. (1985) found a negative relationship between survival of spring chinook (*Oncorhynchus tshawytscha*) from egg to fry and winter flows in the Rogue River, Oregon.

An examination of the flow records for five of the coastal basins where our study streams were located (Hubbard et al. 1984; U.S. Geological Survey, unpubl. data) showed that for run years 1982–84, 18 freshets occurred following peak spawning in the stocked streams and 13 freshets occurred following peak spawning in the unstocked streams (Fig. 4). We estimated emergence timing by assuming an average 108 d (Moring and Lantz 1975) from adult observation until emergence. We found that four freshets occurred following 50% emergence in the stocked streams compared with only one freshet following 50% emergence in the unstocked streams.

The importance of freshets in reducing survival of early spawned coho salmon appears to be demonstrated by the low flows experienced by coho salmon spawned in run year 1984. Fewer and smaller freshets occurred in 1984–85 compared with 1982–83 and 1983–84 (Fig. 4). The average density of juveniles in the stocked streams in 1985 was 23% less than the average density of juveniles in the unstocked streams. However, the average densities of juveniles in the stocked streams in 1983 were 43% less and in 1984 were 47% less than the average densities of juveniles in the unstocked streams.

We conclude from this study that hatchery coho salmon should have the same time of spawning as the wild coho salmon they are supplementing and they should be similar to the wild fish in size at the time of release. We are currently beginning an evaluation of the use of a broodstock that meets these guidelines.

As a result of our study, the release of hatchery presmolts in Oregon coastal streams is currently being concentrated in areas without wild populations. In addition, attempts are being made to identify and develop broodstocks that would be more appropriate than present hatchery stocks for supplementing populations of wild coho salmon.

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