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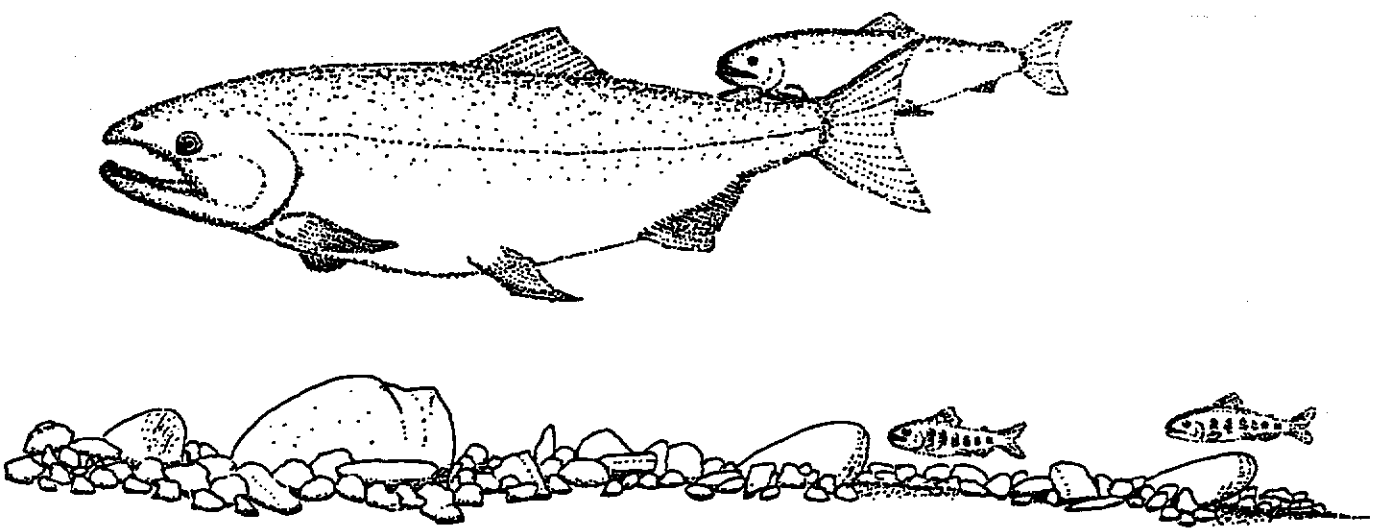
EVALUATION OF PLANTING NATIVE HATCHERY COHO FRY INTO STREAMS CONTAINING WILD COHO FRY



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Evaluation of Planting Native Hatchery Coho Fry into Streams Containing Wild Coho Fry

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CONTENTS

ABSTRACT

We conducted an initial investigation of the effects of planting hatchery-reared wild coho fry into streams containing resident wild fry through the summer of 1989. The ten small, north coastal Washington streams all contained naturally occurring wild fry at varying densities. Hatchery-reared wild fry were planted into eight of the streams. Hatchery-reared fry were consistently larger than resident fry when planted but growth rates were not significantly different through the summer. Although there were some violations of basic study design assumptions, presence of hatchery-reared fry apparently did not cause obvious declines in either hatchery or resident fry. There were no dramatic differences in fry survival between hatchery and resident fry in test streams nor between resident fry in test streams and control streams. We recommend these investigations continue with 1) every test stream having a control stream, 2) varying stocking densities, 3) varying sizes of fish at stocking, 4) evaluation of the effects of up- and downstream migration, 5) further consideration of the dissimilar effects of electrofishing on fry of various sizes, and 6) evaluations of relative success of smolts and adults on the same streams.

INTRODUCTION

The Washington Department of Fisheries (WDF) and the north Washington coastal Treaty Tribes are attempting to increase and stabilize production of natural coho salmon (*Oncorhynchus kisutch*). Since 1984, they have collected wild coho brood to develop their fry source and have recently begun to evaluate the effects of planting those wild-origin coho fry in coastal river systems. In 1989, they planted hatchery-reared coho fry in a number of streams.

Investigation of planting coho salmon fry to augment natural production in underseeded streams has shown that this strategy may be ineffective and can even have negative impact. Planting of non-native coho fry, fry larger than native fry, and fry having dissimilar run timing resulted in reduced wild fry densities and no increase in adult return from either the planted (hatchery) or wild fry (Nickelson et al. 1986).

The U. S. Fish and Wildlife Service shares the goal of rebuilding depressed wild stocks of coastal salmon. In 1989, we agreed to participate in simultaneous fry planting evaluation studies in the Bogachiel and Queets basins. Our objectives in both investigations were similar; to evaluate the impacts of hatchery fry planting, on both wild and hatchery fry, during their first summer. Specifically, our analyses examined potential displacement of wild fry by hatchery fry, differential growth between wild and hatchery fry, and relative survival of wild and hatchery fry.

METHODS

Study Site Selections

Selection of study streams in the Bogachiel Basin was based primarily on location of prior investigations of planted coho fry (Wood 1986). Mill, Coon, Bear, and Hemphill Creeks (Figure 1) satisfied the study requirements for appropriate salmonid species densities and adequate coho seeding levels as anticipated from spawner surveys the previous fall (Bill Wood, WDF, pers. comm.). An unnamed tributary to Coon Creek was selected as a control (Figure 1). We concluded that this stream did not contain planted coho fry and that their immigration would be unlikely due to the stream gradient near the mouth.

Study stream selections in the Queets Basin were based primarily on prior smolt trapping data and knowledge of wild coho seeding levels from spawner surveys. Quinault Department of Natural Resources (QDNR) staff selected Mud, Streater, Drinkwater and North Creeks and they suggested an unnamed tributary to Mud Creek to serve as a control (Figure 2). Here also, we concluded that the control stream did not contain planted coho fry and their immigration was unlikely.

We based study site selections on a combination of priorities: reasonable site access; presence of a representative mixture of habitat types, including pools providing adequate protection for coho fry; and that the stream reach received planted fry. In addition, we located some of the sites at established index reaches where annual electrofishing surveys have been performed to determine coho fry densities. For consistency, we will henceforth refer to a study site as an index. We usually established the length of an index as approximately 100 m. However, in some smaller streams we established proportionately shorter indexes. We maintained index lengths and locations throughout the period of data collection, with the exception of Streater Creek. We shifted the Streater Creek index a few meters downstream after the second data collection to eliminate a small, thickly vegetated slough into which fry probably escaped.

Characteristics of the indexes varied. Among the Bogachiel indexes, Mill and Hemphill Creeks had less gradient and were more enclosed by the forest canopy. While all five stream indexes contained predominantly gravel substrate, the Coon Creek index had the most instream bedrock. Bear Creek was located at the highest elevation and had the steepest gradient. Hemphill Creek had the greatest proportion of pool habitat.

Among the Queets indexes, Streater Creek had the least gradient and was unique in having a mud or silt substrate throughout. All other indexes had predominantly gravel substrate. North Creek had the most instream bedrock. Both Mud and North Creek indexes contained larger proportions of deep pools. All Queets indexes except Drinkwater Creek were located in old growth forest. The Drinkwater Creek index was located in an alder and maple glade adjacent to the Queets River floodplain.

WDF planted coho fry in Mill, Coon, Bear and Hemphill Creeks during mid-May (Table 1). The Quinault Tribe, in cooperation with WDF, planted coho fry in Mud, Streater, Drinkwater and North Creeks in late April (Table 2). All hatchery-reared fry were coded wire-tagged and were missing their adipose fins.

Sampling Procedure

We began data collection in the Bogachiel tributaries just prior to fry planting, but in the Queets tributaries the fry had already been planted before our data collections began. We continued sampling at approximate 4-week intervals until late September-early October.

We captured salmonids in each index with a backpack electroshocker and used the removal method (Zippin 1958) to estimate coho fry populations. We chose the removal method because it works well in small streams and we wanted to avoid additional handling of fish required for a mark-recapture method. On each day of sampling, we first restricted fish movement by placing small mesh block nets at the upper and lower bounds of the index. Each shocking pass consisted of a continuous pass upstream and then a return pass downstream. We normally performed three passes, unless the second pass captured 40% or fewer of both hatchery and wild coho fry captured during the first pass (Washington Department of Wildlife 1981). We identified hatchery fry by absence of the adipose fin. We allowed sufficient time between passes to let uncaptured fry return to their usual stations in the index. (Subyearling trout and yearling trout and coho were enumerated but are not reported here; details can be obtained from the authors.)

We took all reasonable precautions to prevent unnecessary stress to captured fish, primarily because of the risk of biasing study results. We netted stunned fish as quickly as possible. We avoided conditions that cause temperature stress to fish while held in buckets. We were careful to avoid overexposure of fish to the anesthetic solution. And we normally held larger salmonids in buckets separated from coho fry.

We measured weights and fork lengths of up to 50 hatchery and 50 wild coho fry from each sample. Early in the study, we used actual data to determine the sample size required to allow detection of a 3-mm difference in mean length. We concluded that sample size 50 would achieve this ($P<.05$). We weighed anesthetized fry on an electronic balance having an accuracy to 0.1g. We measured fork lengths to the nearest mm. Following their measurement and recovery from the anesthetic, we held captured fish in a live car outside the index.

When the electroshocking work was completed for an index, we measured available habitat. We partitioned the index by habitat type, flagging the bounds of pools, riffles, and glides. We then measured these index partitions for mid-channel length, and useable width at points one-quarter, one-half, and three-quarters of the distance through.

The sampling procedure for Mud Creek was unique in that we kept captured fish separated by habitat type. We placed block nets at the bounds of each habitat type and we replaced fish in the approximate location from where they were captured. Our objectives in this special case were: to eliminate any sampling bias caused by displacement of coho fry from their preferred habitat (pool) due to our sampling impact; and to then assess displacement of wild fry from pool habitat caused by the presence of hatchery fry.

Data Analysis

We calculated standing populations for both wild and hatchery fry, using a computer analysis developed by Van Deventer and Platts (1985). We calculated mean weight, mean fork length, and total biomass for each standing population calculation. From the habitat data we calculated total available surface area (m^2) and surface area of pools only. We then calculated the respective biomass per m^2 total available habitat and number of fry per m^2 pool. We also determined percent survival of fry from each sampling date to the next in each index.

We used analysis of covariance to compare differences between wild and hatchery coho fry mean length, mean weight, biomass per m^2 available habitat, fry per m^2 pool habitat, and percent survival within test stream indexes. We also used analysis of covariance to compare differences between wild fry in test and in respective control stream indexes for the same variables. We used Statgraphics (STSC Inc. 1986) to perform analyses. We assessed potential wild fry displacement from pools in the Mud Creek index by comparing number of captured wild and hatchery fry within individual pools over the study period.

RESULTS

Bogachiel Tributaries

Resident wild and hatchery-reared wild fry generally exhibited similar seasonal trends in densities per m^2 pool in the Bogachiel basin (Figure 3). Resident fry densities followed similar trends between test streams and the control (Figure 3). The pattern of fry biomass per m^2 total habitat was quite variable between resident and hatchery-reared fry, as well as when compared to the control stream (Figure 4). Hatchery-reared fry were consistently larger than resident fry although growth rates of the two groups were apparently similar (Figure 5). Lengths and growth rates were not dramatically different between fry in test and control streams (Figure 5).

In Mill Creek, the standing population of wild fry gradually dropped from 179 in May to 32 in late September (Table 3). The standing population of hatchery fry was only 24 in early June and dropped to 4 by late August. The rate of decline in fry per m^2 pool did not differ markedly from that of the standing population (Figure 3). Available habitat fluctuated through the study period in response to seasonal changes in runoff. In Mill Creek, the maximum change in available habitat was about 25% between any two sampling dates. Fluctuations in available habitat dampened the effect on changes in biomass per m^2 total available habitat (Figure 4).

In Coon Creek, the initial standing populations of both wild and hatchery fry were larger than those in Mill Creek (Table 3). The rates of decline of wild fry in both creeks were generally similar, with a rapid drop during June and early July followed by a less rapid decline through late September (Figure 3). Our initial sampling with both wild and hatchery fry present, on June 6, found nearly equal populations and densities per m^2 pool of wild and hatchery fry (Table 3, Figure 3). Subsequent changes in population and density per m^2 pool over the sampling period were virtually identical (Table 3 and Figure 3). When considering all habitat, however, the biomass of hatchery fry diminished greatly relative to wild fry in midsummer (Figure 4).

We observed an unexpected rise in the Coon Creek standing population and fry per m^2 pool of hatchery fry from late August to late September (Table 3, Figure 3). This was probably due to movement of hatchery fry into the index after August 29. One possibility is that the continued late season decline in available habitat area would affect fry in upstream reaches first, possibly forcing their downstream migration into a reach containing more acceptable habitat.

Initial sampling in Bear Creek apparently preceded the completion of wild coho emergence. Some new fry were drawn from the gravel during electroshocking. Moreover, the standing population had increased sharply by the second data collection, June 8, indicating the recruitment of many new wild fry (Table 3). The wild fry standing population dropped sharply by the next data collection date, July 13, after which it rose again to the previous level. We suspect this drop was due either to equipment malfunction on July 13 or wild fry movement into the index after that date.

The standing population and density per m^2 pool of hatchery fry in Bear Creek remained relatively greater than that of wild fry throughout the study (Table 3, Figure 3). As in Coon Creek, we observed a distinct increase in hatchery fry population in late September. This unexpected increase could have been due to equipment malfunction, fish movements or more successful resistence to capture among larger fry. One possible indication of the latter was the unexpected decreases in hatchery fry mean length and mean weight observed on August 30 (Table 3, Figure 5).

In Hemphill Creek, the standing population of wild fry declined from 245 in May to 78 in late September (Table 3). The standing population of hatchery fry was always smaller, beginning with 93 in June and declining to 30 in late September. An unexpected, small increase was observed in both hatchery and wild fry when we collected data in late August. The declines and increases are nearly duplicated by those of wild and hatchery fry per m^2 pool (Figure 3).

The standing population of wild fry in the control stream index was 116 in early June, and it declined to 40 by the final sampling date in late September (Table 3). No hatchery fry were ever observed in the control index. Fry biomass increased through the early August sampling, but then declined in response to the reduction in population and a slowed rate of increase in mean weight (Table 3). Available habitat increased from June to July but then declined, although relatively little, during the remaining study period. Fry per m^2 pool declined throughout the study period while biomass per m^2 available habitat followed the trend of fry biomass (Figures 3 and 4).

Bogachiel Statistical Analyses

Differences within an index.--Mean lengths and weights were significantly greater in hatchery than in wild fry in all Bogachiel test stream indexes (Table 4, Figure 5), with one exception. The weight of Bear Creek wild and hatchery coho fry was not significantly different although nearly so ($P<.089$).

In analyses of covariance for differences in biomass per m^2 available habitat between wild and hatchery fry, wild fry were significantly greater in Mill Creek while hatchery fry were significantly greater in Coon and Bear Creeks (Table 4, Figure 4). There was no significant difference in biomass per m^2 in Hemphill Creek.

Wild fry per m^2 pool were significantly greater in Mill and Hemphill Creeks while hatchery fry per m^2 pool were significantly greater in Bear Creek (Table 4, Figure 3). There was no significant difference in Coon Creek.

There was no significant difference in percent survival between wild and hatchery fry in three of the streams. In Hemphill Creek, wild fry exhibited significantly better survival than hatchery-reared fry (Tables 3 and 4).

Differences between test and control indexes.--We tested for differences in like factors between wild coho fry in each test stream index and the control stream index. Testing first for wild fry mean length and weight, Bear Creek wild fry were significantly larger than those in the control (Table 4). There were no other significant differences between test and control mean length and weight.

Wild fry biomass per m^2 available habitat was significantly greater in the control stream index than in any test stream index (Table 4, Figure 4). The number of wild fry per m^2 pool was significantly greater in the control stream index than in Mill, Bear, or Hemphill Creek indexes (Table 4). No significant difference was found in Coon Creek.

Percent survival of wild fry was significantly greater in the Hemphill Creek test index than in the control (Table 4). No significant difference was found in Mill, Coon, or Bear Creeks. This, combined with survival results within test streams, indicated that neither wild nor hatchery fry suffered increased mortality due to presence of the other.

Queets Tributaries

Two streams in the Queets basin, Streater and Drinkwater creeks, unexpectedly exhibited trends of increasing fry density as the season progressed (Figure 6). However, in none of the streams was there an obvious decrease of resident wild fry in the presence of hatchery-reared fry (Figure 6). In fact, when considering biomass per m^2 total habitat, resident wild fry appeared to increase more dramatically over the season (Figure 7). As in the Bogachiel basin, hatchery-reared fry were initially larger and growth rates were generally similar through the season (Figure 8).

Standing populations of wild and planted fry in Mud Creek were 136 and 128, respectively, on the initial sampling date, June 16 (Table 5). Both populations declined until after September 13, at which time both increased unexpectedly, perhaps due to fry movement into the index. Mean lengths and weights of hatchery fry were greater than for resident fry, but the difference diminished over the season (Table 5, Figure 8). Biomass of wild fry increased until August, and then declined until it increased sharply with the late increase in standing population. Although planted fry biomass was initially greater than wild, the reverse was true after July.

The values for standing populations of wild and planted fry in Streater Creek were atypical in that they began low and then increased and fluctuated (Table 5). We discovered that Streater Creek index, although the shortest, was quite difficult for fish capture because of hidden bank undercuts and a mud bottom causing turbidity when the crew began to work. We moved the index downstream a few meters, beginning with the third data collection, to avoid a densely vegetated slough into which fry probably escaped. For this reason, the standing population estimates for May and June are suspect. Fluctuations in both wild and planted fry mean length and mean weight were unexpected and indicated that either certain fry avoided capture or that some fry were either entering or leaving the index (Figure 8). Available habitat area declined to half of its original amount by the final sampling date (Table 5). The sharp increase of wild fry in July was in response to both an increase in population and a decrease in habitat (Table 5, Figures 6 and 7).

In Drinkwater Creek, the standing population of wild fry was about ten times that of planted fry (Table 5). The population of wild fry dropped sharply on July 17. We now suspect that lack of full power in the electroshocker caused this anomaly. It is most logical to assume that wild fry were actually present but not captured, and that the graphed point for July 18 should be at the level of the previous and subsequent data collections. Both mean length and mean weight of planted fry were greater than for wild fry over the entire study period (Table 5, Figure 8). Amount of available habitat peaked in June and then continued to decline through the remaining data collections (Table 5). Changes in wild fry per m^2 pool closely followed changes in standing population (Table 5). Increases in biomass per m^2 available habitat largely reflected changes in biomass (Table 5, Figure 7).

The initial standing populations of wild and planted fry in North Creek were 408 and 224, respectively, the highest of any Queets tributary studied (Table 5). Densities of both populations declined with each data collection, except for a slight increase in wild fry on August 9 (Figure 6). On August 9, we observed that stream flow had dropped to a low level. On September 14, the stream was totally dry. Thus, the data collected August 9 concluded our work at North Creek. Planted fry mean length and mean weight was greater than for wild fry throughout the study (Table 3, Figure 8). Available habitat declined with each new observation (Table 5). Planted fry biomass per m^2 available habitat was greater than that for wild fry early in the season but the reverse was true in August (Figure 7).

The wild fry standing population in the control stream index was 86 in mid-June and declined to 27 by October 3 (Table 5). No planted fry were ever observed in this index. A steep decline in fry density occurred between the first and second data collections (Figure 6). Amount of available habitat fluctuated through the study period in response to periods of rainfall, but did not decrease much by the study's completion (Table 5). Changes in fry per m^2 pool closely followed those in standing population (Table 5 and Figure 6). Biomass per m^2 available habitat increased gradually until it declined slightly on October 3 (Figure 7).

Queets Statistical Analyses

Differences within an index.--In analyses of covariance for differences in mean lengths and weights between hatchery and wild fry, hatchery fry were significantly larger in all Queets test stream indexes (Table 4).

Wild fry biomass per m^2 available habitat was significantly greater for wild fry than for hatchery fry in Streater and Drinkwater Creeks (Table 4). No significant difference was found in either Mud or North Creek.

The number of wild fry per m^2 pool was significantly greater than that for hatchery fry in Mud, Streater, and Drinkwater Creeks (Table 4). There was no significant difference found in North Creek.

In analyses for differences in percent survival between hatchery and wild fry, survival of wild fry in Mud Creek was significantly better (Table 4). No significant differences were found in Streater, Drinkwater, or North creeks.

Differences between test and control indexes.--We found no significant differences in mean length or weight of wild fry between test and control indexes (Table 4).

Wild fry biomass per m^2 available habitat was significantly greater in the Drinkwater and North Creek test indexes than in the control (Table 4). There were no significant differences in wild fry biomass per m^2 between either Mud or Streater Creek index and the control index.

In analyses for differences in fry per m^2 pool between wild fry in test and control indexes, fry density in the control was significantly greater than in the Mud Creek index (Table 4). Fry density in the North Creek index was significantly greater than in the control index. There was no significant difference in wild fry density between either Streater or Drinkwater Creek and the control.

In analyses for differences in wild fry percent survival between test and control indexes, no significant difference was found in any comparison. This, together with survival test results from within test streams, indicates that the presence of wild and hatchery fry did not negatively influence the survival of each other.

Mud Creek Wild Fry Displacement

The Mud Creek index contained three pools in which we independently enumerated captured wild and hatchery fry beginning with the June 13 data collection (Table 6). Initially, there were more wild than hatchery fry in the two lower pools, but for the majority of the study, there were more wild fry in all three pools. There were two incidents where wild fry declined from one sampling date to the next while hatchery fry increased or remained unchanged. It is possible that hatchery fry potentially caused wild fry displacement in these cases. However, among the three pools and over the study period, there were 12 opportunities for such displacement (Table 6). Because there were only two possible cases of displacement, we believe hatchery fry had only a minor effect, if any, on wild fry use of pool habitat in Mud Creek.

DISCUSSION

The original study design was partly based on the assumptions that:

1. hatchery-reared fry should be the same size as resident fry when planted;

2. the populations being studied were closed; and

3. the sampling procedures did not differentially influence the two groups of fry.

As the study progressed, potential violations of these assumptions developed. Each is discussed below.

Because of some delays in getting hatchery-reared fry coded wire tagged and because growth could not be slowed in the hatchery, planted fry were consistently larger than resident fry (Figures 5 and 8). This essentially altered the study hypothesis to determining whether planting hatchery-reared wild fry larger than resident wild fry resulted in negative impacts to either fry group.

With regard to the assumption of closed wild or planted fry populations, we blocked the index boundaries during data collection to prevent fry movement from or into the index. However, fish captured in any subsequent data collection may or may not have been the same set of fish, whether wild or planted, captured previously. We must assume that the standing populations we measured in an index potentially represented continuously mobile populations that extended beyond the confines of the index. Unexpected increases in both hatchery and wild populations most likely were caused by immigration. We doubt the increases common to several indexes in late September and October were due to upstream migration of fingerlings for overwintering, as reported by Cederholm and Scarlett (1982), because no noticeable freshets had occurred by these dates.

Perhaps our most important assumption is that our contact with the coho fry did not bias the study results by adversely affecting one group more than the other. Unfortunately, we do not know how many shocked fish eventually died or were unable to compete and left the index. The potential for this trauma is becoming more evident (Sharber and Carothers 1988). The assumption of both wild and planted fry being equally affected by our contact may be doubtful because the planted fry were larger, and larger fish are more susceptible to injury from electrofishing than smaller fish.

Finally, our basic study design included one control index to compare to each of four test indexes. An ideal study design would likely contain pairs of control and test indexes, with each pair located in the same stream and containing similar habitat characteristics (Armour et al. 1983). Paired indexes in the same stream would present the problem of preventing planted fry from entering the control index. In any study stream where this problem could be avoided, the paired study design would be preferable to index pairs in different streams.

Bogachiel Tributaries

Our analysis of Bogachiel data does not indicate clearly that either wild or hatchery coho fry were negatively affected by the presence of the other. Compared to results in the control index, wild fry standing populations in test indexes did not decline at a greater rate over the study period (Table 3). Wild fry mean lengths and weights were not significantly different from those in the control in three of the four test streams; and in the exception, Bear Creek, wild fry were larger than control wild fry, thus further indicating no impact from hatchery fry presence (Table 4). Hatchery fry generally maintained their size advantage over the study period (Table 4, Figure 5), indicating little impact caused by presence of wild fry. There was no significant difference in survival between hatchery and wild fry in all test streams except Hemphill Creek (Table 4). In the Hemphill Creek index, wild fry percent survival was greater than for hatchery fry and was greater than for wild fry in the control, further confirming that hatchery fry did not affect wild fry.

WDF planted Coon and Hemphill creeks at a high rate to ideally obtain total fry densities (wild plus hatchery) approaching 8.00 fry per m^2 and Bear and Mill creeks at a low rate to obtain 2.00 and 3.00 fry per m^2, respectively (Table 1) (Bill Wood, WDF, pers. comm.). Our data indicated total fry densities for time of lowest flow, in late September, for Coon and Hemphill creeks were 0.767 and 0.456 fry per m^2 pool, respectively; and for Bear and Mill creeks total fry densities were 0.588 and 0.157 fry per m^2 pool, respectively. The disparity between our density estimates and the WDF targets is considerable. We suspect it is due to different evaluations of pool habitat type.

Wild fry density, i.e, fry per m^2 pool, was significantly less in test indexes than in the control, except in Coon Creek where it was not significantly different (Table 4). We expected that Coon Creek, of which the control stream is a tributary, would have greater wild fry density than other test streams (Bill Wood, WDF, pers. comm.). This raises the question of suitability of the control for comparison to streams other than Coon Creek and is further argument for more than one control.

Queets Tributaries

Rates of wild fry density decline in test stream indexes were not greater than in the control index, indicating little, if any, effect caused by hatchery coho fry (Figure 6). Standing populations of hatchery fry in both Mud and Streater Creek reached very low levels by September 13. We cannot compare to North Creek because of its drying during the subsequent weeks and Drinkwater Creek always contained too few hatchery fry to make a fair comparison. On the other hand, since few hatchery fry in Drinkwater Creek did not decline, there was probably very little negative impact.

No significant difference between test and control wild fry mean lengths and weights indicated that hatchery fry had little effect on wild fry growth (Table 4). Despite the initial size advantage of hatchery fry, the rates of size increase in test index wild fry were not reduced in Drinkwater and North Creeks (Figure 8). Although there were no significant differences in the slopes of the growth plots, the difference in length between the hatchery and wild fry appeared to diminish by September in Mud and Streater Creeks. Regardless of the cause, wild fry may have been growing faster than hatchery fry.

Implications of the analyses for biomass per m^2 available habitat are less definite. There was significantly greater wild fry biomass in the Streater and Drinkwater Creek indexes but no significant differences in the Mud and North Creek indexes (Table 4). Various confounding factors exist, such as the drying of North Creek and the apparent movement of fry into Mud and Streater Creeks during the late season (Figure 6).

In three of the four test indexes we found no significant difference in percent survival between wild and hatchery fry (Table 4). Mud Creek wild fry survival was significantly better than hatchery fry. We found no significant difference in wild fry percent survival between test indexes and the control. Together, these results further indicate minimal, if any, effect on survival of either wild or hatchery coho fry.

Work in this paper focused only on a short span of coho life. The ultimate test of success or failure of the hatchery supplementation project will be whether natural production of wild coho is increased without altering the natural characteristics of the runs. Thus, it remains important to monitor other stages such as smolts and returning adults to determine whether the trend of little impact observed in this work continues in other stages. It would be particularly advisable to monitor those other stages on the same streams studied here.

CONCLUSIONS

Although there were some concerns about violation of assumptions, we concluded that, in the Bogachiel test indexes, there were no significant negative impacts suffered by either wild or hatchery coho fry resulting from the presence of the other. Neither fry growth nor survival were affected.

Our review of the statistical analyses for the Queets test indexes led us to conclude there were no significant negative impacts upon wild coho fry caused by the presence of hatchery coho fry. While there was some evidence of possible negative effects upon hatchery fry, statistical analyses clearly showed no negative impact on their survival.

Our study results indicated that neither wild nor hatchery fry were seriously affected by outplanting. Initial concerns about the larger size of hatchery fry appear to be unfounded. If anything, the hatchery fry being larger than wild fry would more likely have caused a negative impact on wild fry than if fry were of equal size.

RECOMMENDATIONS

The present study should be considered a preliminary investigation. Because of concerns regarding the lack of more than one control stream per basin, effects of size of fry at planting, density of fry at stocking, and migration of fry into and out of the study indexes, this study should be repeated. We make the following specific recommendations:

1. there should be as many control indexes as test indexes and, where possible, they should be established as test vs. control pairs, by stream;

2. in one year, several test streams should be planted with a range of sizes to study the effects of size at planting;

3. in another year, several streams should be planted with a range of densities to determine the effects of carrying capacity on the relative success of wild and hatchery-reared fry;

4. studies should be designed to increase knowledge of potential coho fry movement into (if not out of) study indexes;

5. implications of dissimilar effects on fry caused by electroshocking should be examined carefully; and

6. evaluation should be continued through all possible life stages using observations from the same streams studied here.

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Table 1. Pre-season estimated densities of wild coho fry and densities of hatchery-reared coho fry required to seed experimental streams to desired levels.

Stream	Estimated natural density	Planned hatchery density	Total planned density	Marked fry released
Coon Creek	6.43	1.57	8.00	10,109
Hemphill Creek[a]	4.93	5.03	8.00	1,205
Bear Creek	0.53	1.47	2.00	3,408
Mill Creek	2.23	0.77	3.00	8,808

[a] 25,520 additional fry were planted above the falls on Hemphill Creek.

Table 2. Coho fry planting information for Queets tributaries in 1989.

Stream	Number of tagged fry planted	Approximate distance planted (mi)	Planting rate (fry/0.1 mi)
Mud Creek	25,200	2.6	969
North Creek	24,900	1.2	2,075
Drinkwater Creek	1,000	0.7	143
Streater Creek	500	0.4	125

Table 3. Bogachiel tributary coho fry population, density, survival, and habitat values in 1989.

Date	H/W *	Estimated population	Mean length	Mean weight	Biomass (g/m^2)	Total habitat (m^2)	Fry per m^2 pool	Biomass per m^2**	Percent survival
				Mill Creek					
08-May	W	179	39.2	0.9	161.1	458.2	0.77	0.35	
05-Jun	W	170	42.3	0.87	147.9	471.4	0.71	0.31	1.000
	H	24	53.6	2.1	50.4	471.4	0.10	0.11	1.000
10-Jul	W	91	47.5	1.55	141.1	517.8	0.35	0.27	0.535
	H	12	59.6	2.85	34.2	517.8	0.05	0.07	0.500
31-Jul	W	52	51.8	1.85	96.2	484.3	0.21	0.20	0.571
	H	22	61.9	2.97	65.3	484.3	0.09	0.13	1.833
28-Aug	W	53	60.5	3.02	160.1	570.2	0.18	0.28	1.019
	H	4	72.5	4.85	19.4	570.2	0.01	0.03	0.182
25-Sep	W	32	61.8	3.25	104.0	450.7	0.14	0.23	0.604
	H	4	76.5	5.5	22.0	450.7	0.02	0.05	1.000
				Coon Creek					
09-May	W	424	37.3	0.6	254.4	473.5	2.02	0.54	
06-Jun	W	331	36.9	0.52	172.1	474.8	1.57	0.36	1.000
	H	314	54.6	2.1	659.4	474.8	1.49	1.39	1.000
11-Jul	W	120	44.5	1.13	135.6	474.8	0.57	0.29	0.363
	H	241	59.5	2.71	653.1	474.8	1.15	1.38	0.768
01-Aug	W	84	49.7	1.49	125.2	487.0	0.39	0.26	0.700
	H	113	62.0	2.92	330.0	487.0	0.53	0.68	0.469
29-Aug	W	54	56.9	2.25	121.5	478.8	0.26	0.25	0.643
	H	61	67.9	3.75	228.8	478.8	0.29	0.48	0.540
26-Sep	W	39	56.0	2.02	78.8	452.0	0.20	0.17	0.722
	H	114	68.5	3.7	421.8	452.0	0.57	0.93	1.869
				Bear Creek					
10-May	W	7	37.9	0.7	4.9	204.9	0.07	0.02	
08-Jun	W	29	45.5	1.6	46.4	263.6	0.16	0.18	1.000
	H	53	55.5	2.27	120.3	263.6	0.29	0.46	1.000
13-Jul	W	11	56.4	2.33	25.6	223.1	0.08	0.11	0.380
	H	47	61.2	2.88	135.4	223.1	0.34	0.61	0.887
02-Aug	W	30	61.4	3.01	90.3	221.3	0.22	0.41	2.727
	H	46	64	3.53	162.4	221.3	0.34	0.73	0.979
30-Aug	W	21	65.8	3.72	78.1	211	0.16	0.37	0.700
	H	35	59.9	2.76	96.6	211	0.27	0.46	0.761
27-Sep	W	17	68.9	3.95	67.2	178.2	0.15	0.38	0.810
	H	48	74.3	4.96	238.1	178.2	0.43	1.34	1.371

Table 3. Continued.

Date	H/W *	Estimated population	Mean length	Mean weight	Biomass (g/m^2)	Total habitat (m^2)	Fry per m^2 pool	Biomass per m^2**	Percent survival
				Hemphill Creek					
11-May	W	245	38.0	0.60	147.0	477.0	0.98	0.31	
09-Jun	W	187	39.4	0.74	138.4	459.9	0.77	0.30	1.000
	H	93	56.0	2.25	209.3	459.9	0.39	0.46	1.000
14-Jul	W	119	47.9	1.50	178.5	445.5	0.51	0.40	0.636
	H	64	59.4	2.72	174.1	445.5	0.27	0.39	0.688
03-Aug	W	112	51.3	1.89	211.7	501.6	0.42	0.42	0.941
	H	35	59.9	2.76	96.6	501.6	0.13	0.19	0.547
31-Aug	W	123	55.9	2.44	300.1	459.9	0.51	0.65	1.098
	H	54	65.4	3.49	188.5	459.9	0.22	0.41	1.543
28-Sep	W	78	58.5	2.72	212.2	449.2	0.33	0.47	0.634
	H	30	69.0	4.20	126.0	449.2	0.13	0.28	0.556
				Control Stream					
07-Jun	W	116	38.8	0.69	80.0	150.7	1.23	0.53	1.000
12-Jul	W	96	47.2	1.35	129.6	165.3	0.87	0.78	0.828
02-Aug	W	93	52.6	1.98	184.1	162.6	0.79	1.13	0.969
29-Aug	W	69	54.0	2.02	139.4	154.1	0.62	0.90	0.742
27-Sep	W	40	57.9	2.67	106.8	156.7	0.34	0.68	0.580

* H = Hatchery-reared fry, W = Wild fry
** Biomass per m^2 available habitat

Table 4. Summary of results from ANCOVA for wild and hatchery coho fry in eight test and two control streams. The following represent fry that were significantly larger or greater in number: H for hatchery fry; W for wild fry; C for control stream wild fry; and T for test stream wild fry. NS indicates non-significance (P = 0.05).

Stream	Mean length	Mean weight	Biomass per m	Fry per m pool	Percent survival
Within Streams					
Mill	H	H	W	W	NS
Coon	H	H	H	NS	NS
Bear	H	NS	H	H	NS
Hemphill	H	H	NS	W	W
Mud	H	H	NS	W	W
Streater	H	H	W	W	NS
Drinkwater	H	H	W	W	NS
North	H	H	NS	NS	NS
Wild: Between Test & Control					
Mill	NS	NS	C	C	NS
Coon	NS	NS	C	NS	NS
Bear	T	T	C	C	NS
Hemphill	NS	NS	C	C	T
Mud	NS	NS	NS	C	NS
Streater	NS	NS	NS	NS	NS
Drinkwater	NS	NS	T	NS	NS
North	NS	NS	T	T	NS

Table 5. Queets tributary coho fry population, density, survival, and habitat values in 1989.

Date	H/W *	Estimated population	Mean length	Mean weight	Biomass (g/m^2)	Total habitat (m^2)	Fry per m^2 pool	Biomass per m^2**	Percent survival
				Mud Creek					
16-May	W	136	38.3	0.57	77.5	517.0	0.66	0.15	1.000
	H	128	50.1	1.40	179.2	517.0	0.62	0.35	1.000
13-Jun	W	88	45.3	1.29	113.5	556.7	0.29	0.20	0.647
	H	62	52.8	2.00	124.0	556.7	0.20	0.22	0.484
19-Jul	W	67	56.5	2.59	173.5	578.4	0.21	0.30	0.761
	H	40	61.7	3.29	131.6	578.4	0.13	0.23	0.645
08-Aug	W	53	61.8	3.34	177.0	502.2	0.19	0.35	0.791
	H	29	67.3	4.06	117.7	502.2	0.10	0.23	0.725
13-Sep	W	39	68.3	4.24	165.4	470.0	0.15	0.35	0.736
	H	15	70.1	4.33	65.0	470.0	0.06	0.14	0.517
04-Oct	W	76	71.7	5.47	415.7	458.3	0.30	0.91	1.949
	H	28	72.8	5.43	152.0	458.3	0.11	0.33	1.867
				Streater Creek					
17-May	W	25	44.2	1.16	29.0	82.5	0.30	0.35	1.000
	H	3	47.7	1.30	4.0	82.5	0.04	0.05	1.000
12-Jun	W	58	47.4	1.49	86.4	77.5	0.75	1.11	2.320
	H	10	53.5	2.03	20.3	77.5	0.13	0.26	3.333
21-Jul	W	76	56.3	2.37	180.1	45.2	1.68	3.98	1.310
	H	14	60.6	2.77	38.8	45.2	0.31	0.86	1.400
10-Aug	W	62	55.1	2.22	137.6	41.6	1.49	3.31	0.816
	H	15	59.7	2.61	39.1	41.6	0.36	0.94	1.071
14-Sep	W	70	64.4	2.63	184.1	43.2	1.62	4.26	1.129
	H	12	68.5	3.02	36.2	43.2	0.28	0.84	0.800
05-Oct	W	64	58.7	2.98	190.7	41.6	1.54	4.58	0.914
	H	14	59.9	3.34	46.8	41.6	0.34	1.13	1.167
				North Creek					
18-May	W	408	40.4	0.70	285.6	360.9	2.11	0.79	1.000
	H	224	50.8	1.60	358.4	360.9	1.16	0.99	1.000
14-Jun	W	243	46.0	1.22	296.5	351.7	1.29	0.84	0.596
	H	184	53.8	2.04	375.4	351.7	0.98	1.07	0.821
20-Jul	W	135	49.1	1.62	218.7	333.5	0.76	0.66	0.556
	H	90	58.2	2.55	229.5	333.5	0.50	0.69	0.489
09-Aug	W	141	56.3	2.34	329.9	259.0	1.02	1.27	1.044
	H	80	60.3	2.85	228.0	259.0	0.58	0.88	0.889

Table 5. Continued.

Date	H/W *	Estimated population	Mean length	Mean weight	Biomass (g/m^2)	Total habitat (m^2)	Fry per m^2 pool	Biomass per m^2**	Percent survival
				Drinkwater Creek					
15-May	W	100	45.2	1.10	110.0	233.7	0.65	0.47	1.000
	H	8	52.1	1.85	14.8	233.7	0.05	0.06	1.000
15-Jun	W	90	48.2	1.58	142.2	249.8	0.55	0.57	0.900
	H	7	60.7	2.90	20.3	249.8	0.04	0.08	0.875
17-Jul	W	45	55.4	2.30	103.5	246.6	0.28	0.42	0.300
	H	6	61.7	3.08	18.5	246.6	0.04	0.08	0.857
07-Aug	W	91	60.3	2.84	258.4	227.3	0.61	1.14	2.022
	H	7	68.9	4.16	29.1	227.3	0.05	0.13	1.167
12-Sep	W	66	62.5	3.11	205.3	177.4	0.57	1.16	0.725
	H	8	70.6	4.47	31.3	177.4	0.07	0.18	1.143
03-Oct	W	66	68.8	4.38	289.1	169.5	0.59	1.71	1.000
	H	4	78.0	5.55	22.2	169.5	0.04	0.13	0.500
				Control Stream					
15-May	W	86	40.2	0.70	60.2	354.7	1.05	0.17	1.000
15-Jun	W	46	46.3	1.38	63.5	337.3	0.59	0.19	0.535
17-Jul	W	44	55.6	2.45	107.8	371.9	0.51	0.29	0.957
07-Aug	W	35	60.4	3.03	106.0	288.1	0.53	0.37	0.795
12-Sep	W	35	66.4	3.89	136.2	300.2	0.50	0.45	1.000
03-Oct	W	27	70.7	4.79	129.3	312.5	0.37	0.41	0.771

* H = Hatchery-reared fry, W = Wild fry
** Biomass per m^2 available habitat

Table 6. Wild and hatchery fry captured in pools in the Mud Creek index.

Sampling date	Lower pool		Middle pool		Upper pool	
	Wild	Hatchery	Wild	Hatchery	Wild	Hatchery
13-Jun	17	12	16	10	10	19
19-Jul	11	5	12	10	21	11
08-Aug	15	12	13	6	11	3
13-Sep	6	2	11	3	8	5
04-Oct	22	6	21	7	23	11

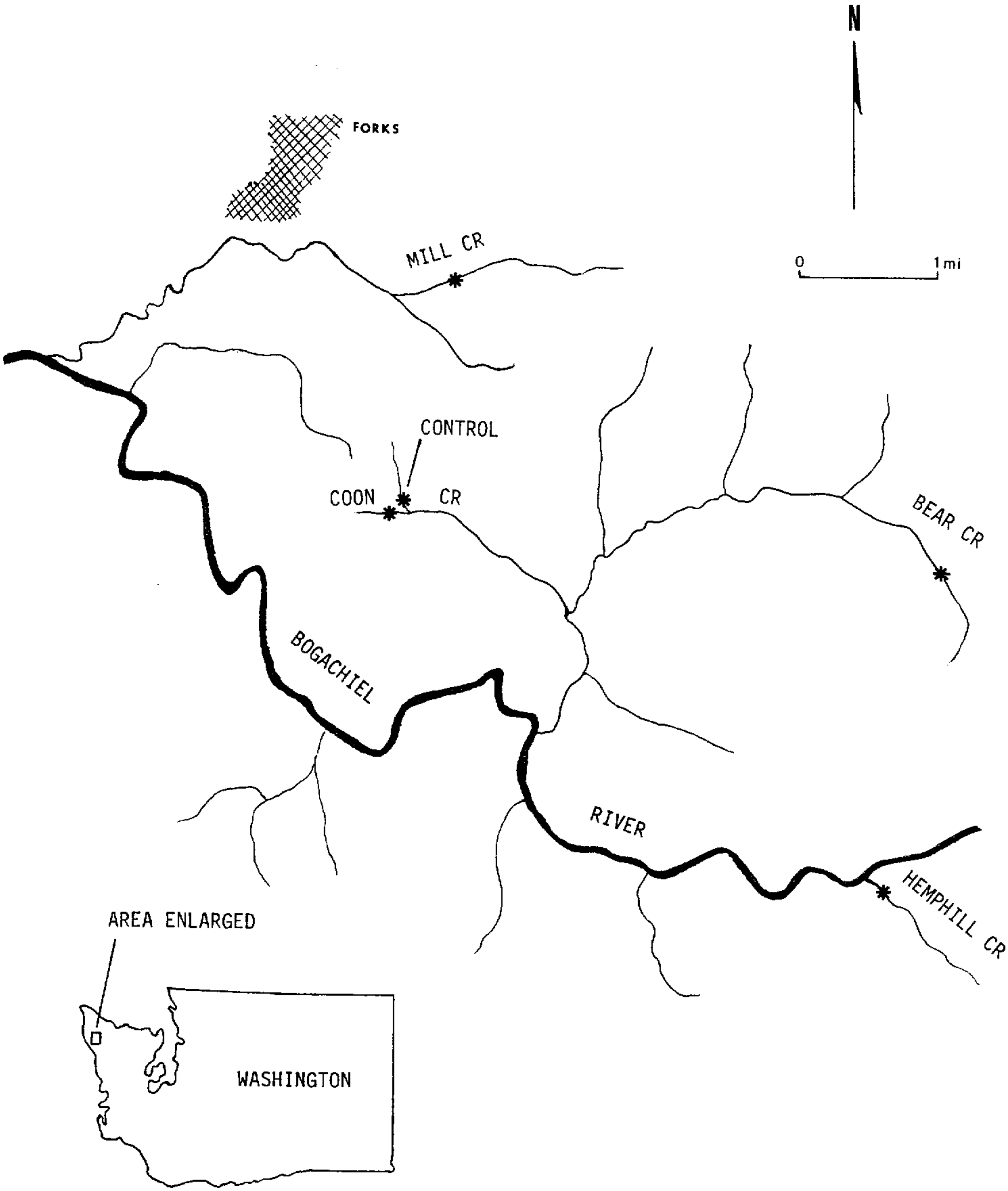

Figure 1. Index locations (✱) in the Bogachiel River basin.

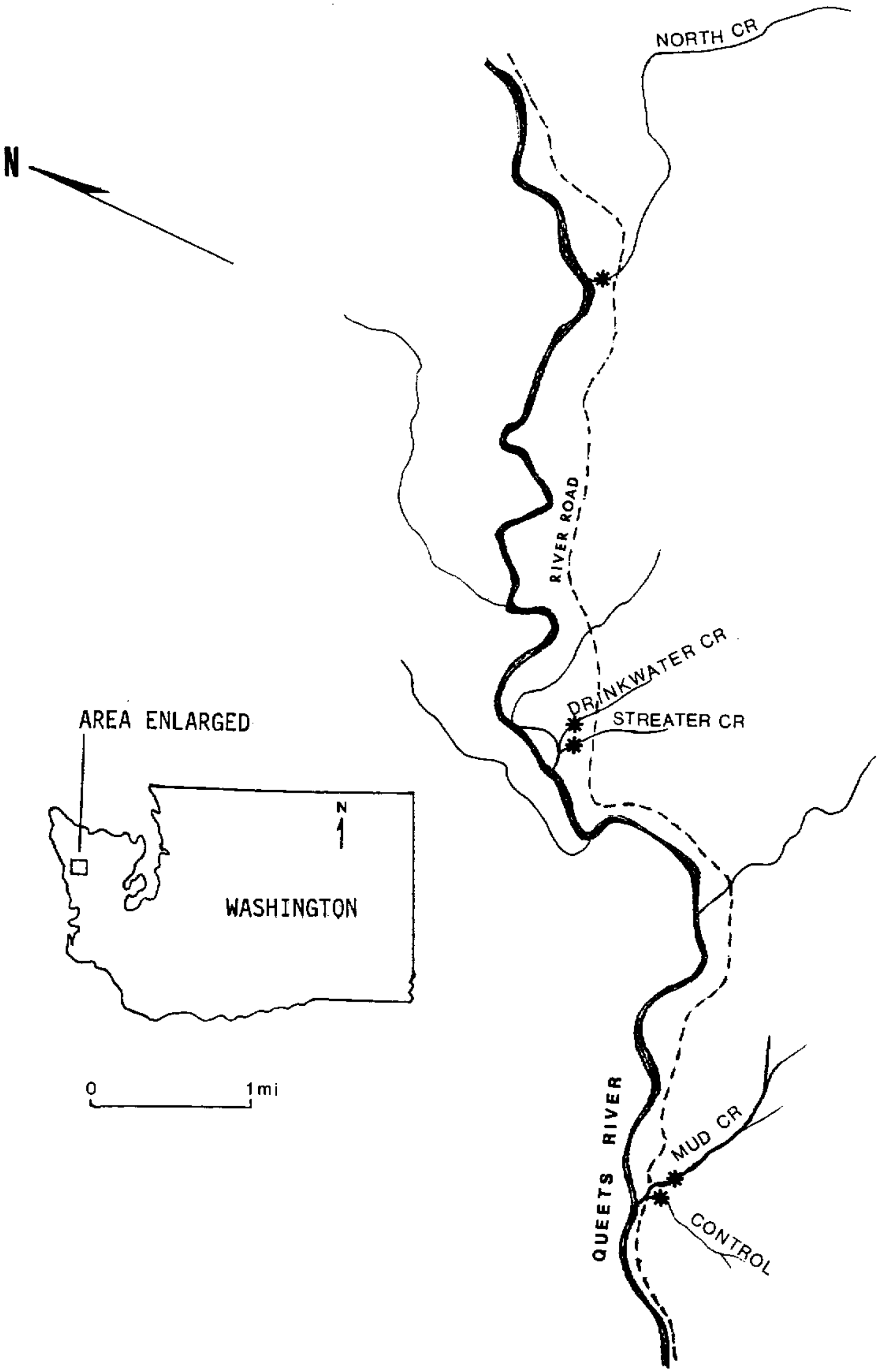

Figure 2. Index locations (✱) in the Queets River basin.

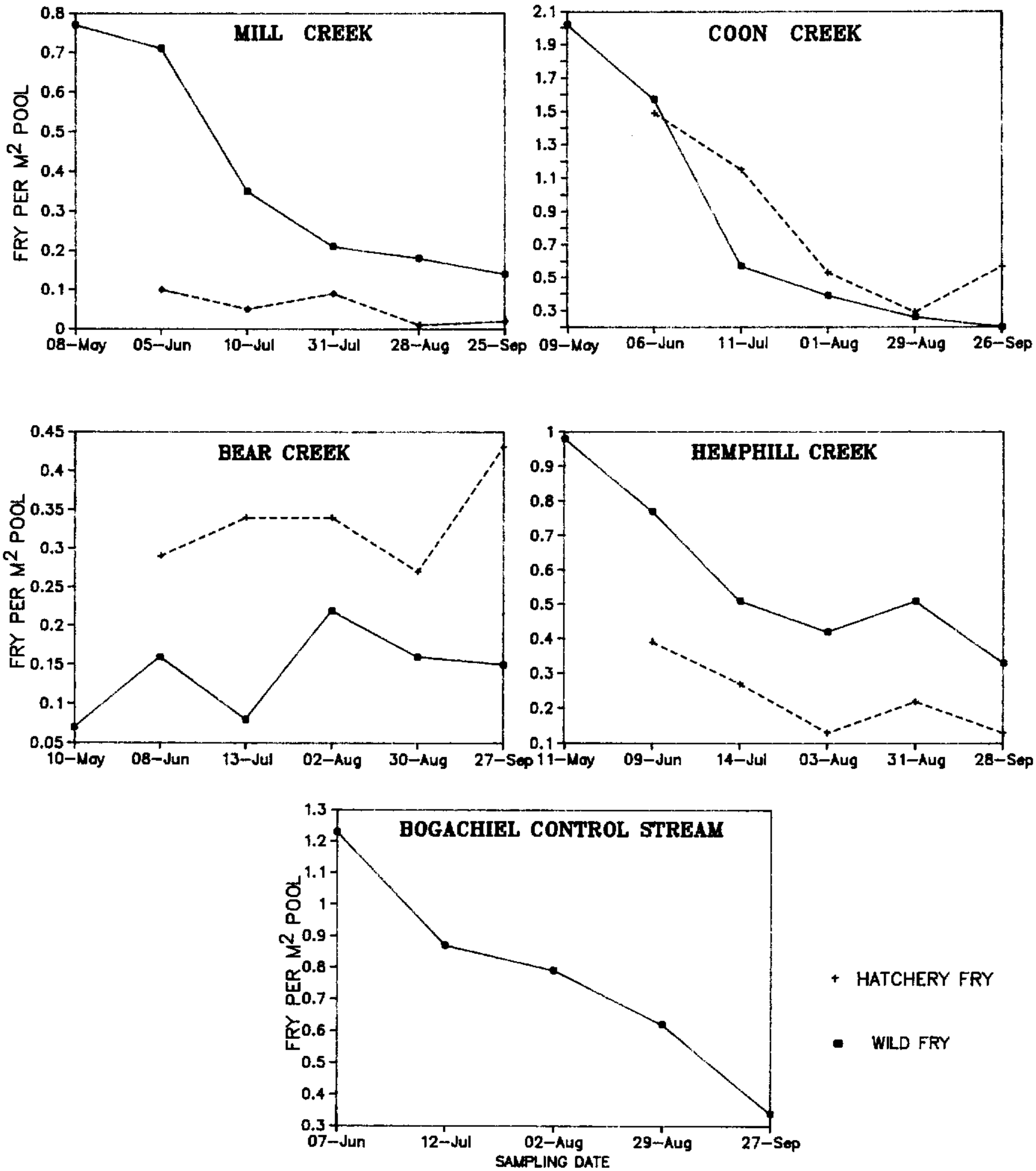

Figure 3. Wild and hatchery coho density, as fry per m^2 pool, in Bogachiel tributaries.

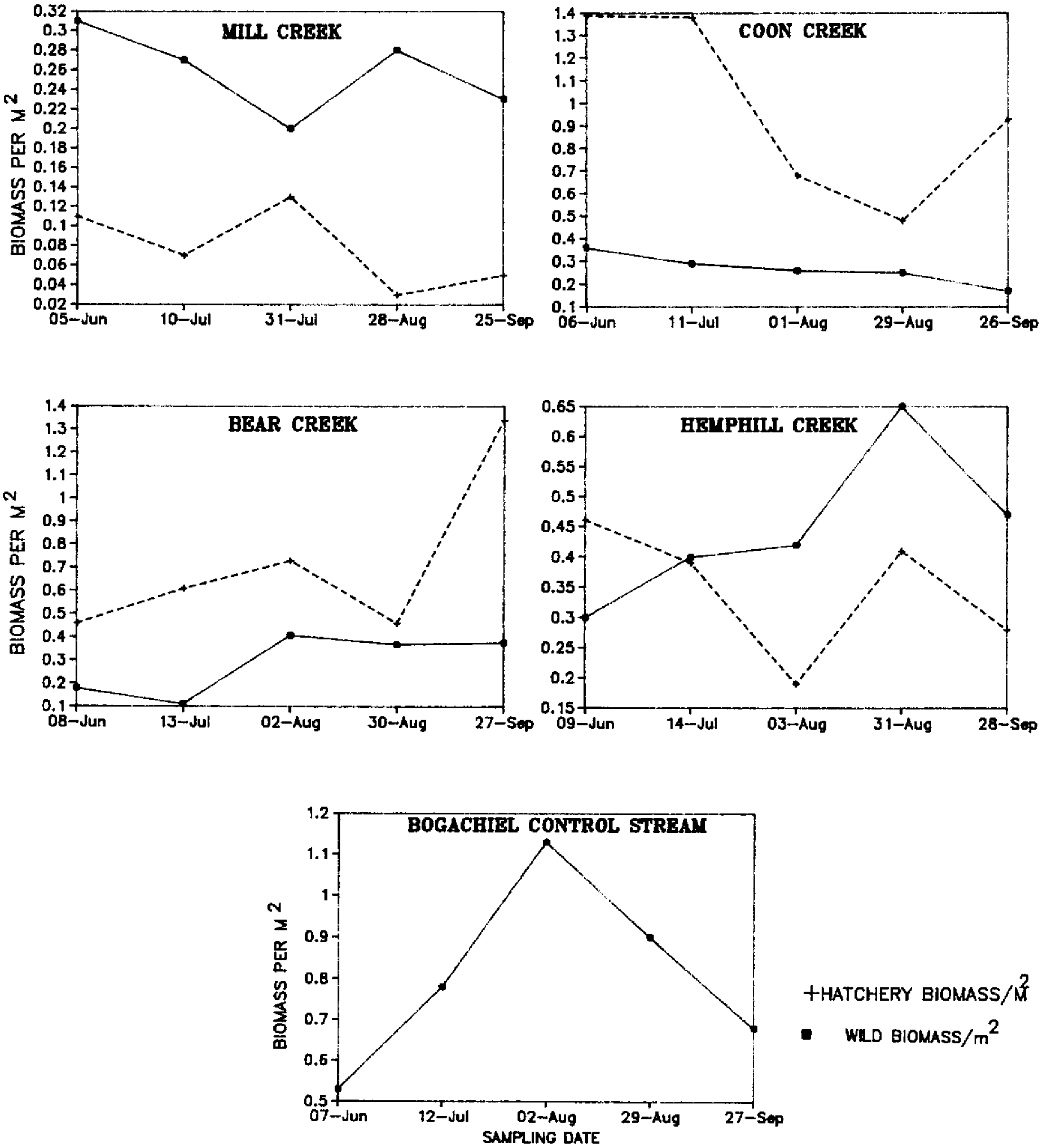

Figure 4. Wild and hatchery coho fry biomass per m^2 habitat in Bogachiel tributaries.

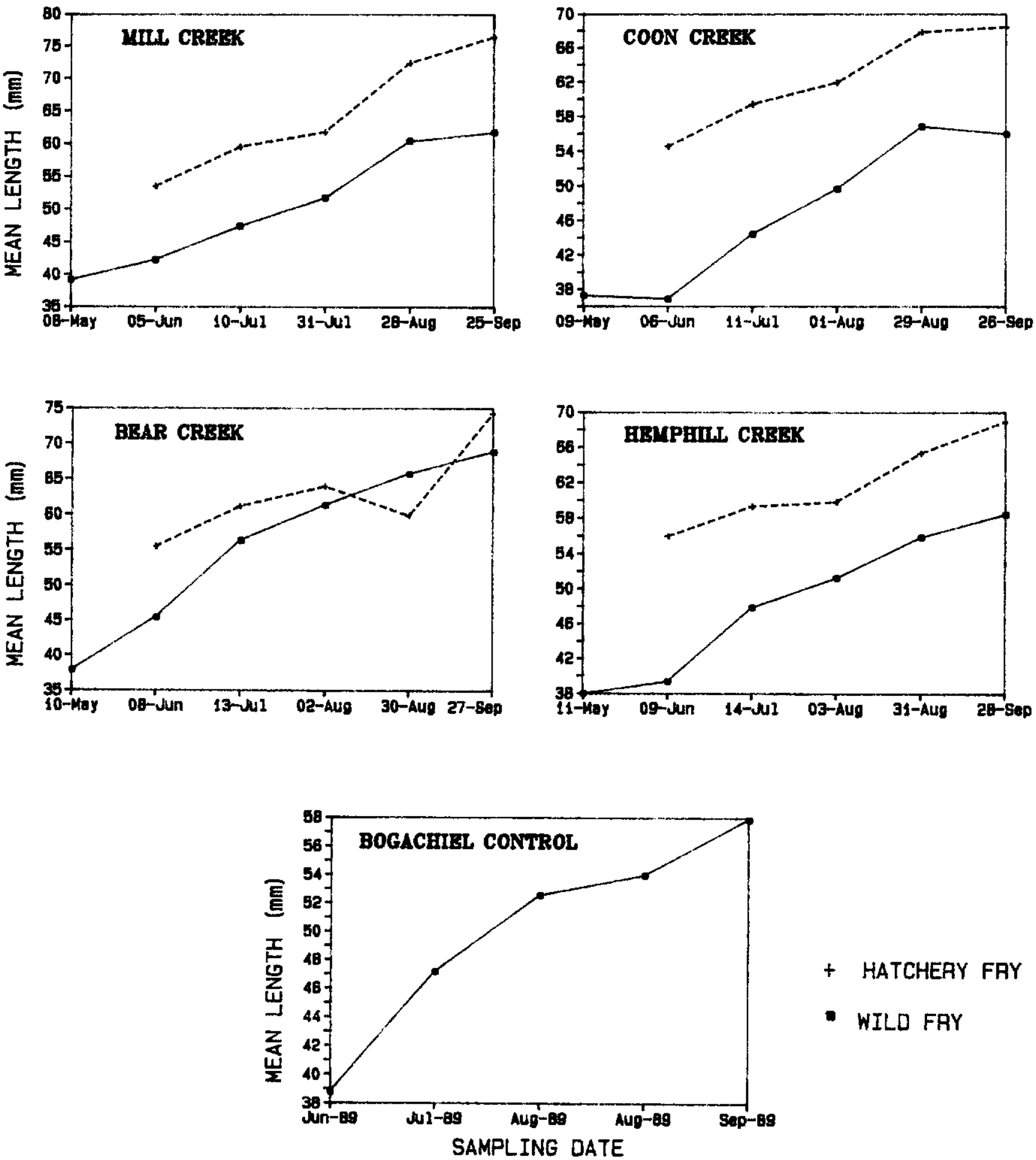

Figure 5. Compared wild and hatchery coho fry mean fork lengths on all sampled dates in the Bogachiel tributaries.

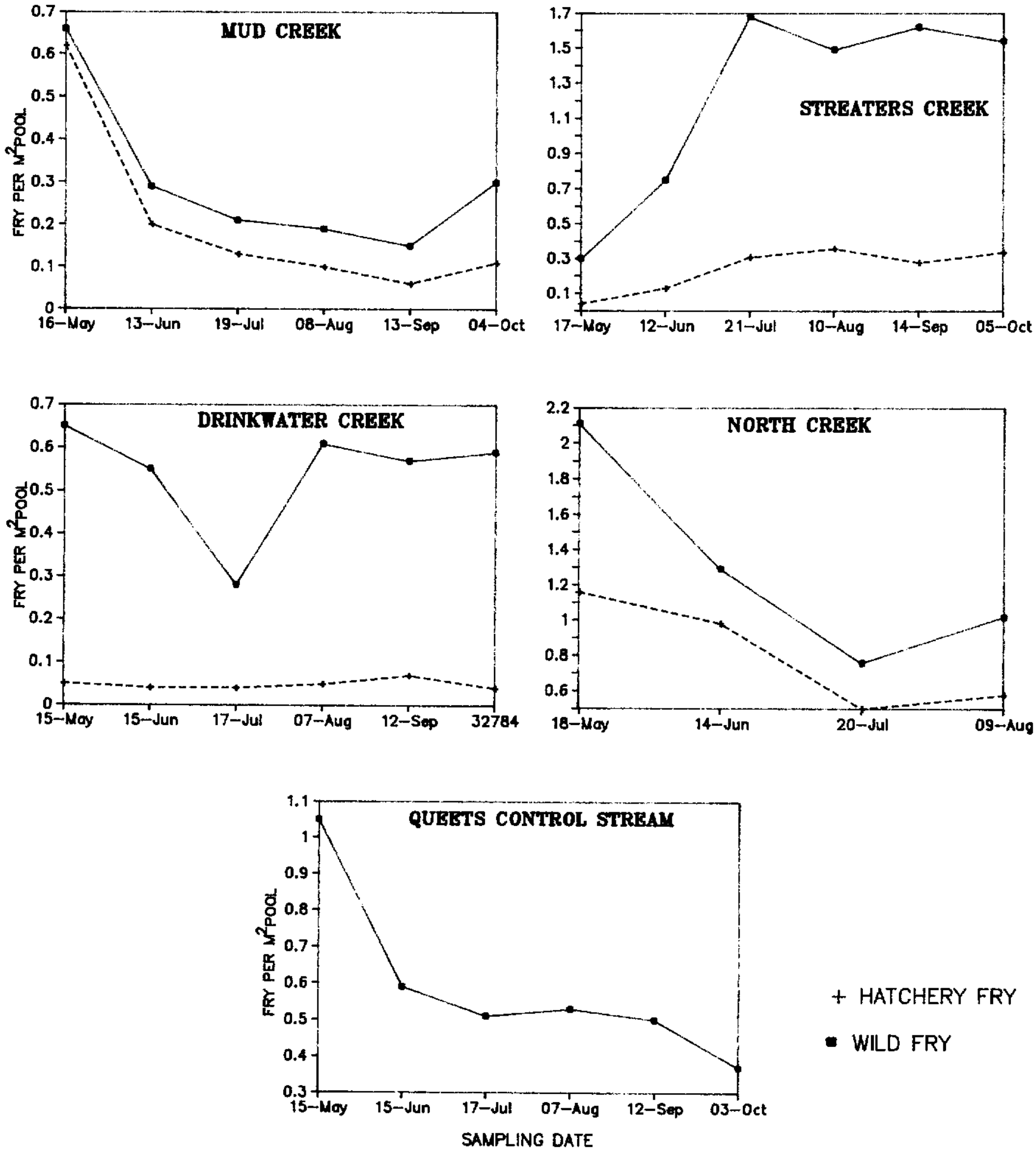

Figure 6. Wild and hatchery coho fry density, as fry per m^2 pool, in Queets tributaries.

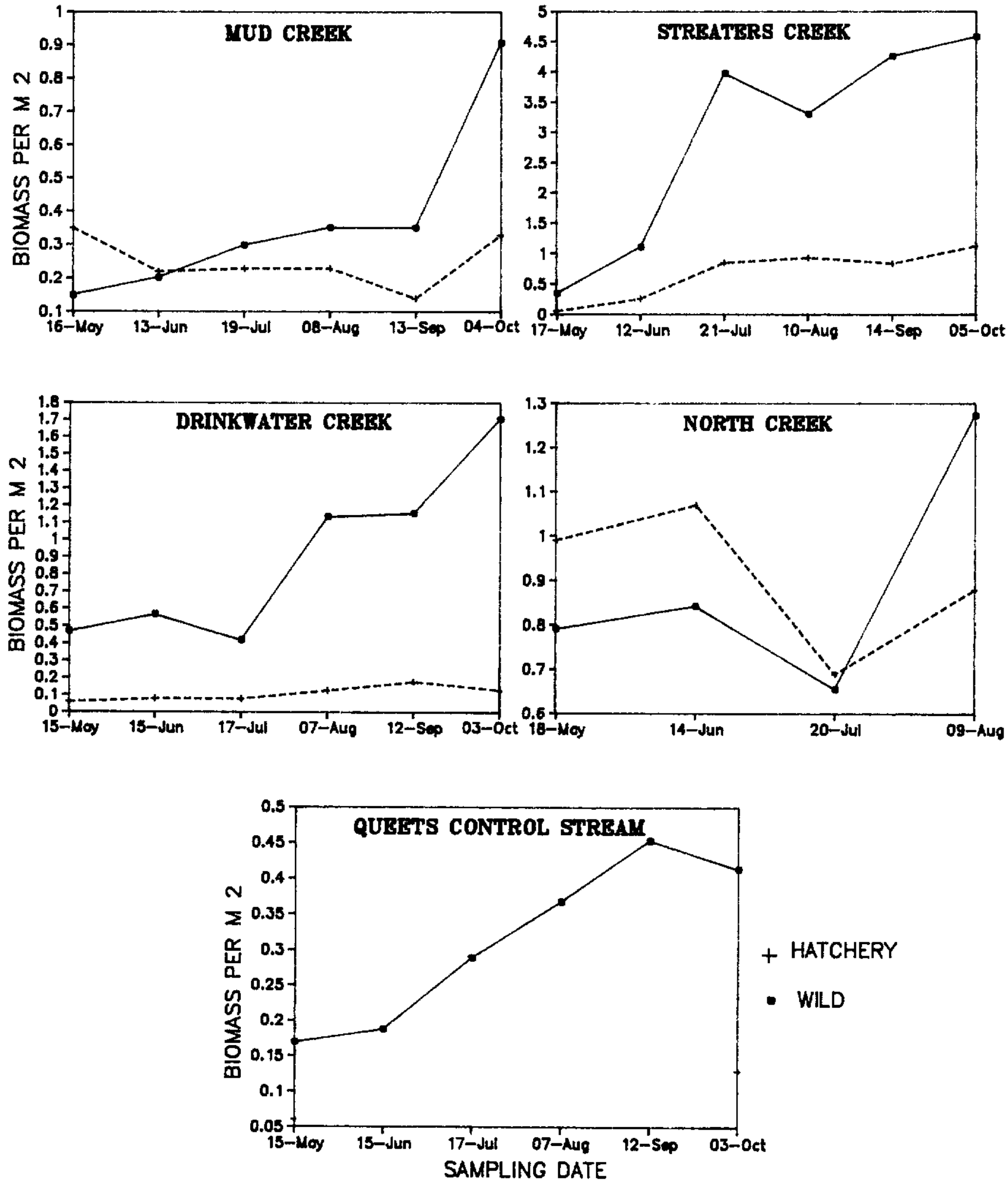

Figure 7. Wild and hatchery coho fry biomass per m^2 habitat in Queets streams.

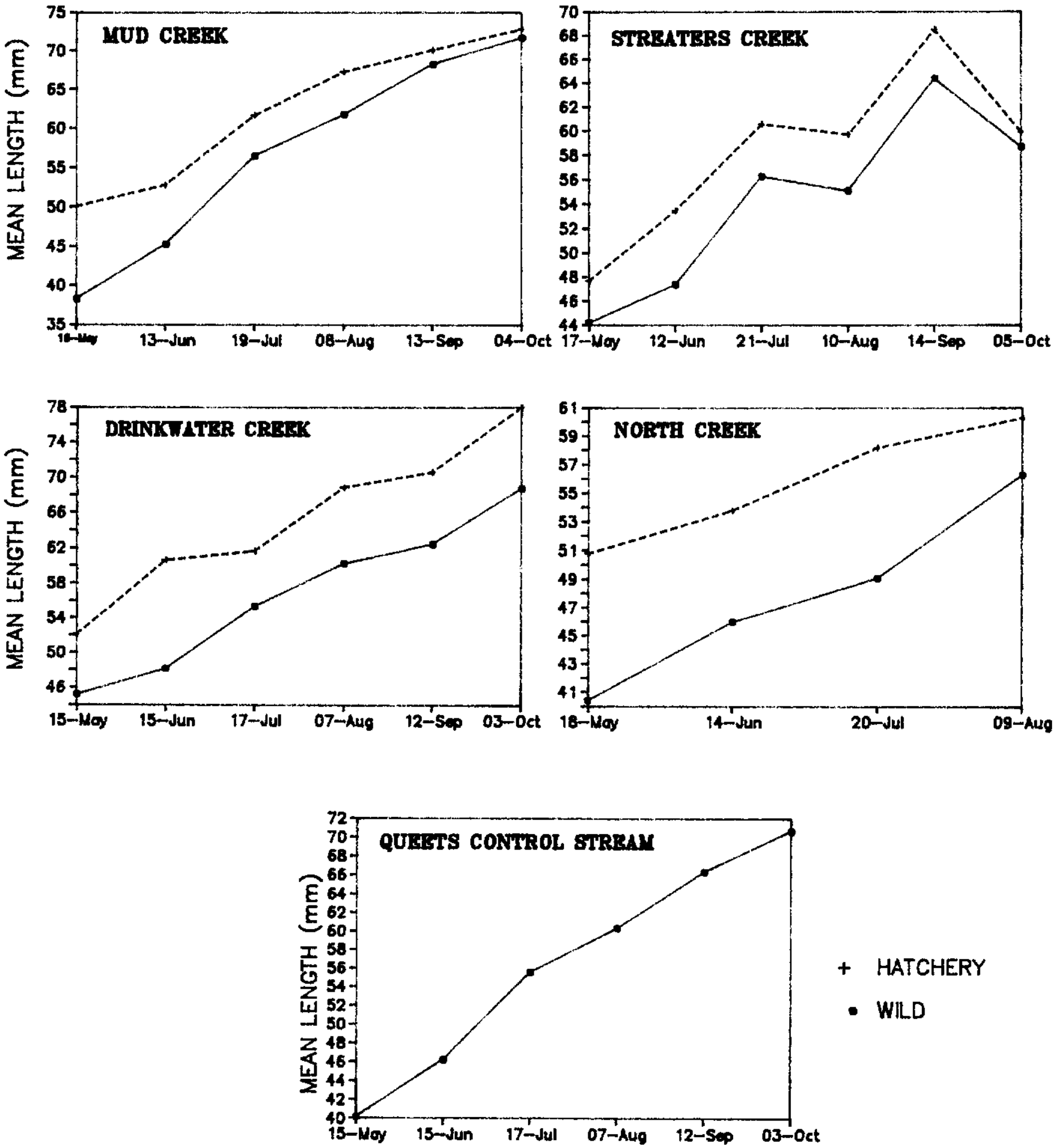

Figure 8. Compared wild and hatchery coho fry mean fork lengths on all sampled dates in the Queets tributaries.