Approaches to Supplementing Coho Salmon in the Queets River, Washington

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The artificial propagation and release of fry, fingerlings or smolts to increase natural production (supplementation) is receiving increased attention as a means of addressing problems associated with chronic weak stocks of Pacific salmon (*Oncorhynchus* spp.). We describe pertinent findings from two years of fry outplants of coho salmon (*O. kisutch*) in the Queets River system and 11 years of monitoring freshwater production. Results of these studies indicate that fry plants did not increase natural production except in circumstances when natural seeding was extremely low. Smolts released from specific locations in the system likely provides the best approach to produce adults for harvest while increasing natural spawning escapements. Natural production would be increased by a natural dispersal of newly emerged fry into underutilized habitats.

INTRODUCTION

Low abundances of wild coho salmon runs in western Washington have posed major difficulties to fisheries managers since the late 1970s. Annually, managers have been faced with how to split the proverbial baby; in this case, how to balance escapement needs of weak wild stocks with the fishery objectives of tribal and non-tribal constituents. Fisheries management has become increasingly complex as a result of concerns over these runs (Morishima 1984; Hayman and Moore 1992).

The Washington Department of Fisheries (WDF) and Quinault Treaty Area (QTA) Tribes[2] initiated a project in 1984 to alleviate chronic weak stock conditions by attempting to increase natural production using supplementation techniques. Spawning escapements were believed to be lower than necessary to sustain production and associated fisheries for stocks produced in coastal rivers, especially in the Queets River (Lestelle et al. 1984; Wood 1984). By outplanting artificially propagated juveniles into the natural environment, it was hoped that natural production would be bolstered, thereby improving run status and fishery opportunities.

The term supplementation refers to the planting of hatchery produced fish in an attempt to increase natural production (Miller et al. 1990; RASWG 1991). The use of supplementation is being given wide attention in some areas of the Northwest, especially in the Columbia Basin (RASWG 1991). However, to date few projects have evaluated its effectiveness for Pacific salmon. Concerns exist about the outplanting of hatchery reared fish into the natural environment and particularly over their possible genetic and ecological effects on wild populations (Steward and Bjornn 1990).

These concerns are exemplified in the study of Nickelson et al. (1986), which evaluated outplants of hatchery coho salmon fingerlings into Oregon coastal streams. Stocking of fingerlings, produced from hatchery broodstock, increased the total densities of coho salmon juveniles (wild and hatchery combined) in late summer. However, the subsequent production of naturally produced juveniles from spawners in

[2]Quinault, Quileute, and Hoh tribes, as signatories to the Quinault River Treaty with the United States.

streams previously stocked was significantly less than in streams that had not been stocked. The authors concluded that the reproductive success of supplementation fish was less than wild fish due to the earlier spawning timing of hatchery stock fish. Presumably, earlier spawning resulted in earlier fry emergence. Early emergence can coincide with periods of high flows and result in reduced survival (Hartman and Scrivener 1990). Nickelson et al. (1986) suggested that future supplementation efforts should first develop suitable broodstocks having the characteristics of the wild fish to be supplemented.

Extensive monitoring of freshwater production in the Queets system has been conducted since the late 1970s by the Quinault Indian Nation and WDF. Distribution and abundance of spawners are estimated through redd surveys of the mainstems and tributaries. Smolt yields are assessed from various tributaries and ponds, as well as from the entire Clearwater subbasin (Figure 1). Smolt yields from the tributaries are determined by trapping near the mouths of the streams (Lestelle and Curtright 1987), while the Clearwater subbasin estimate is obtained using a mark-recapture technique with a scoop trap located near the mouth (Seiler et al. 1991). Smolt yields at up to 18 sites are assessed each year. Since 1981, we have annually tagged up to 40,000 wild coho salmon smolts, providing opportunities to assess the production characteristics of the natural population. This information serves as much of the basis for evaluating supplementation in the basin.

In this paper, we describe two approaches to supplementing natural coho salmon runs in the Queets River: fry outplants and smolt releases. Fry outplanting experiments were conducted in the 1980s, while smolt releases are being proposed for future evaluation.

LOCATION

The Queets River is located on the west slope of the Olympic Mountains on the Olympic Peninsula (Figure 1). It drains an area of 1,165 km^2 and is comprised of two major sub-drainages: the Clearwater subbasin, which drains about one third of the entire area, and the remainder of the system. These two subbasins are distinctly different, the Clearwater being a non-glacial system whereas the Queets is glacial fed. The floodplain of the Queets River contains a much greater number of the terrace channels discussed by Peterson and Reid (1984) than found along the Clearwater River. These channels include the wall-base and percolation channel habitats, which are heavily used for overwintering by coho salmon (Peterson and Reid 1984).

PROJECT DEVELOPMENT

Genesis

Two workshops, sponsored by the National Marine Fisheries Service, QTA Tribes, U.S. Fish and Wildlife, and WDF, were held in the early 1980s to address questions about the productive capacities of Washington coastal rivers for coho salmon and appropriate spawning escapement levels (Lestelle et al. 1984). A panel of experts on coho salmon ecology and population dynamics was asked to review available information on the stocks and help identify appropriate spawning escapement targets.

The panel concluded that spawning escapements then occurring were significantly lower than levels needed to achieve maximum sustainable harvests (MSH) from the stocks. Higher escapements were recommended, though uncertainties about the underlying stock-production relationships made it difficult to identify precise targets. The panel advised that MSH escapements were likely to fall within ranges which could be determined through habitat measurements and suggested that escapements be varied within these ranges to learn more about the underlying production relationships.

From a practical standpoint, the panel's recommendations went beyond what fisheries managers could do to increase escapements by regulating domestic fisheries. Fishing along the Washington Coast and in the terminal areas had already been substantially curtailed, and it appeared that little could be gained from further reductions in these fisheries (Lestelle et al. 1984). Harvest management now focused on the protection of weak coho stocks, with the Queets run often being the controlling stock.

The Queets supplementation project was an attempt to increase production and alleviate harvest management problems. Success would result in improved fishery opportunities on other intermingled, healthier stocks in both ocean and river fishing areas. In addition to augmenting natural production, the project was committed to maintaining existing and presumably adaptive characteristics of the natural run, such as river entry and spawning timing.

Approach

The strategy selected was to stock coho salmon fry produced from native broodstock. By increasing fry seeding through outplanting it was assumed that smolt production would thereby be increased. With adequate logistical support, fry could be placed anywhere in the basin, thereby maximizing production potential. Moreover, this life stage was selected to minimize undesirable physiological and behavioral traits potentially caused by hatchery confinement.

The project was intended to be adaptive and respond to new information as it became available. It was unclear whether supplementation was needed to simply boost the Queets stock to a higher level of production, thereafter maintaining it through harvest controls, or if periodic outplanting would be needed to overcome production deficiencies.

The project was implemented in two phases. Phase I, begun in 1984, consisted of broodstock development and a small scale fry outplant in spring of 1984 to gain information about coded wire tagging fry, stocking techniques and logistics (Table 1). Broodstock runs were established by first capturing and spawning wild fish in the Queets system, rearing their progeny in facilities outside the drainage, then releasing these fish as smolts back into the Queets system at release-recapture facilities. Adult fish returning to these facilities were used to produce the fry for outplanting. The broodstock runs were developed by releasing up to 280,000 smolts annually (Table 1). Approximately 20% of the broodstock needed each year for smolts consisted of wild parents to guard against inadvertent artificial selection and loss of adaptive characteristics. Broodstock was collected throughout the run to maintain natural spawning timing. After an initial attempt to establish one broodstock run using spawners from throughout the drainage, the project was modified to develop two separate broodstock sources - one derived from Clearwater spawners for outplanting into that subbasin and one for the remainder of the Queets system.

Phase II of the project began in 1988 when sufficient numbers of broodstock returned to begin large scale outplants (Table 1). Two million fed fry were released in spring, 1989 (McHenry et al. 1989). The fish were distributed to achieve an estimated fry density of hatchery and wild fish combined of 5.0 fish/m^2 in stocked tributaries. Natural fry densities were projected from estimates of spawner abundances in each stream. Streams that had projected natural fry densities greater than 5.0 fish/m^2 were not stocked. All hatchery produced fry not designated for tributaries were released into the Clearwater and Queets river mainstems. Fish were dispersed by helicopter throughout the mainstems and by bucket brigades in the tributaries. Care was taken to disperse fry throughout the reaches being supplemented. Mean fish weight per release group ranged between 0.9 and 1.6 g (289-523 fish/pound). Nine representative groups were marked and coded wire tagged to monitor movements, survival and fishery contributions. The Snahapish River (a tributary of the Clearwater River) and the upper Queets River were not stocked to serve as controls for evaluating project success. The Snahapish River was monitored for juvenile and spawner abundance, whereas the upper Queets River was to be monitored for long term changes in spawner abundance.

Plans to conduct similar stocking operations after 1989 were thwarted by an isolation of viral haemorrhagic septicemia (VHS) at the WDF Soleduck Hatchery in fall, 1989. That facility, located in the Quillayute drainage north of the Queets, was being used to propagate Queets fish for this project. Discovery of the virus interrupted project implementation and led to the realization that new facilities were needed to handle the Queets project. Since then, the project has been under review to determine the need and approach for further supplementation initiatives in the drainage.

FINDINGS

Only the results of fry stocking pertinent to juvenile survival and movement are presented in this paper. Work is currently in progress to evaluate the survival of fish to the adult stage.

The survival of coded wire tagged fry to the smolt stage in the Clearwater subbasin ranged from 2.7 to 10.8% and 1.4 to 7.3% for the 1984 and 1989 experiments, respectively (Table 2). These rates were assumed to be less than those for untagged fish released at the same sites. Adjustments for untagged survival rates were based on comparative survival of untagged and tagged fry released into a stream upstream of a barrier to anadromous migration. The only coho salmon present in that stream were stocked fish, enabling us to estimate differential survival between tagged and untagged fish. Tagged fish survived at 73% the rate of untagged fish in 1984 and 44% the rate of untagged fish in 1989. Survival rates for untagged fish released into all other areas of the Clearwater subbasin were estimated from representative tagged fish adjusted for differential survival estimated for that year (Table 2).

Survival was related to the habitat where fish were released. For brood year 1988, when stocking attempted to achieve a density of 5.0 fish/m^2 in tributaries, fry did not remain and survive in steep tributaries as well as those released into low gradient tributaries; overall survival (including fish that left the release streams prior to winter) also tended to be less (Table 2). Fry released directly into the mainstem river did not survive as well as fish stocked into tributaries.

Many of the stocked fry redistributed in the Clearwater subbasin much like natural fish, with fish moving considerable distances in the subbasin to overwintering sites. Similar to survival rates, fry movement was dependent upon where the fry were planted. Fish stocked into high gradient tributaries were more likely to move than those stocked into low gradient tributaries. For example, of the fry outplanted into Christmas Creek (a high gradient tributary), more were recovered as smolts in off-channels ponds than those outplanted into Shale Creek (a low gradient tributary) (39% vs. 9%). For fry outplanted into low gradient tributaries, more were recovered in their respective release streams compared to elsewhere in the Clearwater subbasin (Shale Creek, 90% vs. 10%, for example). For fry outplanted into the Clearwater mainstem, a majority (66%) were recovered in off-channel ponds, 29% were recovered in low gradient tributaries and few (5%) were recovered in high gradient tributaries.

The Washington Department of Fisheries (D. Seiler, pers. comm.) estimated that supplementation fish comprised approximately 8% and 35% of the total smolt yields from the Clearwater subbasin in 1985 and 1990 (brood years 1983 and 1988; Table 2). Fry stocking in brood year 1988 was the only attempt to produce a significant increase in total smolt production.

Although supplemented fish comprised a substantial proportion of the smolts following the large fry plant, we concluded that the overall smolt yield increased little, if any, over what would have occurred without stocking (Figure 2). Natural fish were apparently displaced without an increase in production benefits for that year. However, when natural seeding was extremely low, as was the case in 1984, fry supplementation appeared to increase production for one stream (Shale Creek). Compared to smolt production from Snahapish River for the same year, smolt production from Shale Creek appeared to have increased by roughly 20-30% as a result of fry stocking.

PRODUCTIVE CAPACITY

The results of fry outplanting, though limited, combined with 11 years of monitoring spawner abundances and smolt yields in the Queets River basin, provide a basis for reviewing the question of the river's productive capacity for coho salmon.

In evaluating supplementation in the system, two alternative hypotheses have emerged, each with different implications to supplementation. One hypothesis is that the river system has, on average, been fully seeded for coho salmon over the past 11 years. A second hypothesis is that the productive capacity of the system is significantly higher than reflected by current smolt yield levels.

The first hypothesis is based in part on the apparent lack of increase in Clearwater River smolt production as spawning escapements increase over the observed range (Figure 2). Total smolt yields in that subbasin have varied between 45,000 and 95,000 over an eleven year period, with no indication of greater yields at higher escapements or stocking levels. For example, smolt yield following the one large fry outplant (68,000; 95% C.I. = 65,761 - 69,938) fell within the middle of the observed range of yields, despite supplementation fish comprising a substantial portion of the total yield.

Under the first hypothesis, variation in smolt yield is influenced primarily by environmental fluctuations with spawner abundance having relatively minor effects. If the average current smolt yield is less than historic production, or more variable, it is likely due to increased environmental instability. If this hypothesis is true, the goal of increasing and stabilizing fisheries could potentially be achieved by merely increasing exploitation rates and reducing spawning escapement levels. To continue supplementation would produce little or no increase in natural production, while risking adverse effects on natural productivity through maladaptive genetic alterations. In a typical year, supplementation fish would at best simply replace natural fish, without realizing any increase in overall production.

The second hypothesis is based on available information about juvenile life history and habitat utilization patterns in the Clearwater subbasin. This hypothesis suggests that the absence of an increase in smolt yield with increasing escapements (Figure 2) is not a good indicator of the productive capacity of the river system. Important production characteristics are lost within the composite stock-production picture of the entire population. Data collected on abundance at various points in the freshwater life cycle and at different locations (Figure 1) demonstrate that production characteristics vary substantially within the Clearwater subbasin. These characteristics appear to be shaped by the extent of movement between habitats that occur for juvenile coho salmon in the Clearwater system (Peterson and Reid 1984; Scarlett and Cederholm 1984).

To evaluate which of these hypotheses may be true, we developed a conceptual model to describe how coho salmon use different parts of the river system at different life history stages. A general pattern of habitat use is evident for the Clearwater River system based on a synthesis of available production and fry supplementation data. We believe the same pattern is true for the entire Queets River basin. A conceptual diagram illustrates how coho salmon use the river system at different life history stages (Figure 3). Five major habitats are identified: (1) the lower mainstems, (2) relatively low gradient tributaries associated with the lower mainstems, (3) off-channel ponds, located mainly along the lower mainstems, (4) the upper mainstems, and (5) relatively high gradient tributaries associated with the upper mainstems.

Based on this habitat classification, with the exception of the low gradient tributaries, the relative utilization of these areas varies markedly between life stages (Figure 3). The low gradient tributaries generally support relatively high densities of coho salmon year round. Within the Queets basin, the low gradient tributaries most typify streams considered by biologists to be highly productive for coho salmon, that is, small, slower velocity streams with an abundance of pool habitat interspersed with woody debris (Sandercock 1991). In contrast, the steeper gradient tributaries support relatively few coho juveniles during summer and winter, although they are used extensively for spawning (Figure 3). These streams contain comparatively little habitat preferred by juvenile coho salmon during the immediate post emergence life (e.g., see Reeves et al. 1989) or during the summer rearing and overwintering life stages (e.g., see Nickelson et al. 1992).

The movements of fish between areas immediately following emergence, and again just prior to winter, change the habitat utilization patterns seasonally (Figure 3). Such movements adjust a fish population's spatial distribution to meet changing habitat needs through time (Northcote 1978). This is best illustrated for fish that originate in the steeper gradient areas of the basin. Those streams can have spawner densities among the highest in the basin. Most coho salmon fry produced there, however, apparently disperse into the mainstems prior to summer. There, dispersal likely continues until suitable habitat is found either in the mainstem proper or in side channels, principally at sites in and around woody debris accumulations (Peterson and Reid 1984). Some fish move into off-channel ponds for summer rearing. Mainstem residents, which grow more rapidly than juveniles in tributaries, move into the ponds with the onset of fall freshets to overwinter (Peterson and Reid 1984).

Some of the juveniles that rear in the mainstems originate in low gradient tributaries (Figure 3). These fish likely come mainly from very short tributaries or spawning sites near the lower reaches of longer tributaries (Lindsay 1974; Peterson and Reid 1984).

Au (1971) observed that the "dispersiveness" (i.e., propensity for movement) of a newly emerged coho salmon fry is related to the likelihood of encountering habitat suitable for colonization within several days of emergence. The exposure of a newly emerged fry to habitat suitable for colonization apparently affects the developmental state of the fish and its readiness to settle and cease dispersal. Preferred habitat is associated mainly with the shallow stream margins of low velocity and backwater areas. Au (1971) concluded, therefore, that "dispersiveness" in this early stage is primarily related to density independent mechanisms, though intraspecific competition may prolong the period of initial dispersal. Au's observations suggest that fry produced in steep "habitat poor" tributaries would have a greater tendency to disperse over longer distances than fish produced in low gradient "habitat rich" streams. This suggests that many of the fish that rear in mainstem areas and off-channel ponds during summer and winter are produced in the steeper spawning areas of the basin.

Following migration to and from the ocean, fish that migrate to sea from off-channel ponds are believed to return primarily to their natal streams (Peterson 1985); spawned out carcasses that were coded wire tagged as smolts at the ponds have been recovered in the high gradient spawning areas in addition to other spawning sites in the system (Quinault Indian Nation, unpublished data).

Because of the spring and fall redistributions of fish, most smolts originate from two of the five areas, the lower gradient tributaries and off-channel ponds (Figure 3). These two areas differ as to the extent they are utilized compared to their smolt production capacities. Smolt yields from lower gradient streams typically show little or no positive correlation with numbers of parent spawners, exemplified by the relationship for Shale Creek (Figure 4). Other streams show similar patterns. These streams exhibit substantial interannual variation, however, which we believe is due to environmental fluctuations. Shale Creek was supplemented with fry in two years (brood years 1983 and 1988).

An exception to the pattern for low gradient streams is seen in Snahapish River, the largest tributary to the Clearwater (Figure 5). The stream is substantially larger than other tributaries in the subbasin and contains abundant habitat of the type used by juvenile coho salmon. It appears to have produced at less than its productive potential in most years since 1981.

At current levels of spawning escapement, the numbers of smolts produced in ponds along the Clearwater mainstem appear to be directly related to spawner abundances in areas upstream in the subbasin (Figure 6; shown for a composite of five ponds). The same pattern exists, incorporating more years of data, between spawning escapement and the numbers of fall immigrants moving into a single pond (Paradise Pond) from the mainstem Clearwater River (Figure 7; data from Cederholm et al. 1988; J. Cederholm and W. Scarlet, pers. comm.). As spawning escapement increases, there is a direct increase in the numbers of juveniles utilizing mainstems and ponds. The 1988 data point, the year of the large fry outplant, indicates that movement into the pond was not higher than would be expected without supplementation. At present, we are uncertain why the additional fry from supplementation did not increase utilization of the ponds. Fry were planted into the Clearwater mainstem by helicopter in groups of several thousand fry. It is possible that releasing fry in the mainstem and in large groups resulted in negative interactions between hatchery reared and wild fry or the inability for the additional fry to fully utilize available habitat.

The available data suggest that the mainstems during summer and the off-channel ponds during winter are underutilized compared to their potential. The difference between current utilization and capacity for both is likely greater in the Queets subbasin than in the Clearwater because of a much larger amount of suitable mainstem and pond habitat located there. Up to 30% of the total Clearwater smolt yield is currently produced in ponds; the percent of the total basin's yield at full seeding of these habitats could potentially exceed 50% of the total.

We conclude that production potential is not being realized system-wide. Current production levels, compared to potential, vary between habitat areas. Production in each area appears to respond differently to seeding levels and environmental variation. Peterson (1985) previously suggested that production characteristics for the Clearwater mainstem and off-channel ponds are dramatically different than for tributaries. Our analysis supports Peterson's characterization of production patterns in the Clearwater subbasin.

If the second hypothesis is true then it would not be possible to meet the goals for fisheries by merely increasing exploitation rates. An increase in exploitation rate would reduce spawner abundance and reduce smolt production from off-channel ponds (Figure 6).

APPROACH FOR FUTURE SUPPLEMENTATION

We have proposed that supplementation continue in the Queets River system to further evaluate the potential for increasing production and alleviating weak stock effects to fisheries. Future efforts would test whether supplementation can be used to increase natural production from specific habitats, for example, the mainstem-pond complex.

Based on our findings to date, we believe that the most effective approach to supplement this habitat complex would be to increase spawner abundances in the steeper spawning streams by releasing smolts into or near those streams. If spawner abundances can be increased in those streams, fry recruitment to the mainstem rivers should be boosted. This, in turn, should increase smolt yields from overwintering ponds along the mainstem rivers.

The hatchery reared smolts, which would all be marked for positive identification at older life stages, would be released from small semi-natural ponds to be constructed along or near the steep gradient tributaries. These ponds would be located in the upper portions of the subbasins. The ponds would provide short-term acclimation for the smolts prior to their release seaward. We used a similar means to acclimate the hatchery reared smolts released in 1987 for broodstock development. The smolt release-adult recapture facility that was to be used for the project in the Clearwater subbasin was still under construction at the time, necessitating that we improvise for the smolt release that year. We, therefore, used a small semi-natural pond that had been constructed to enhance overwintering habitat for natural juveniles. Upon their return in the fall of 1988, the hatchery produced fish dispersed to spawning areas throughout the general vicinity where the pond was located, adding significantly to natural spawning. Moreover, the smolt to adult survival of the fish acclimated in that pond was approximately equal to that of the wild Clearwater run in the same years (an average survival year). This is the only time that we have observed such high survival for hatchery reared salmon in either the Queets or Quinault river; survival of hatchery fish is normally 10-50% of that of wild fish. The improved survival could have been at least partly due to the natural rearing conditions that the fish experienced prior to their release. Preliminary findings of the National Marine Fisheries Service suggest that the survival of hatchery reared salmon could be significantly improved by exposing the fish to natural-like habitat prior to release (D. Maynard, pers. comm.).

The relatively small acclimation ponds that would be needed for the project could be constructed inexpensively in key areas of the river system. Cederholm et al. (1988) reported on one approach for creating natural overwintering ponds; we have used a similar, less costly, technique to create temporary ponds for acclimating and releasing hatchery fish. Natural ponds, if located in the appropriate areas, could be used for acclimating smolts as well.

The hatchery reared juveniles would be transported to the acclimation sites approximately one month prior to smoltification. The fish would be fed while in the ponds, then allowed to emigrate volitionally.

Adults that return from these releases should return to the general vicinity of the ponds and disperse to spawning areas. Any fish attempting to enter the ponds would find access to the ponds blocked by temporary structures to prevent access by adult fish. By increasing the numbers of spawners in the high gradient spawning streams, which tend to be located high in the subbasin, fry seeding to downstream areas should be increased through the process of natural dispersal. This approach to increasing fry recruitment in the mainstems would avoid competitive interactions between naturally produced and hatchery produced fry.

An important element of the work would be the use of natural broodstocks. Each year, natural broodstocks would be captured from the river system; no first generation hatchery produced fish would be used for artificial propagation. All hatchery produced fish would be identified by external marks. The risk of adverse effects to genetic fitness would be lessened by ensuring that no first generation hatchery fish are used for broodstock (RASWG 1991). The number of broodstocks to be used remains to be determined, but special care would be given to maintaining existing genetic diversity within the system.

Detailed planning for the proposed initiative is currently underway utilizing guidelines described in RASWG (1992) for supplementation projects. The guidelines provide a series of planning steps for describing objectives, assessing risks, and defining monitoring and evaluation activities.

A small scale feasibility project is now in progress in the drainage. Adults will return to spawn in the fall of 1993.

SUMMARY

Fry were outplanted into tributaries of the Queets River in spring of 1984 and 1989. Fry outplanted in 1989 were produced from a native broodstock which was developed during the 1980s. We conclude that total smolt production increased little, if any, following the large fry outplant in 1989, despite the fact that supplemented fish accounted for 35% of smolt production for the Clearwater subbasin.

The apparent lack of increase in Clearwater River smolt production as spawning escapements increase suggests that the system has been fully seeded over the past 11 years. However, from data collected at various points in the freshwater life cycle we show that production characteristics vary within the Clearwater subbasin. Small and medium sized low gradient tributaries appear to be at full capacity for smolt production in most years. On the other hand, large streams, and more importantly, mainstem rivers and off-channel ponds are underutilized compared to their potential.

Smolt supplementation is being proposed for future evaluation. Smolt releases would be used to increase spawner abundances in specific areas of the basin. If spawner abundances can be increased in steep streams this should increase fry recruitment to the mainstems, which, in turn, should increase smolt yields from overwintering ponds.

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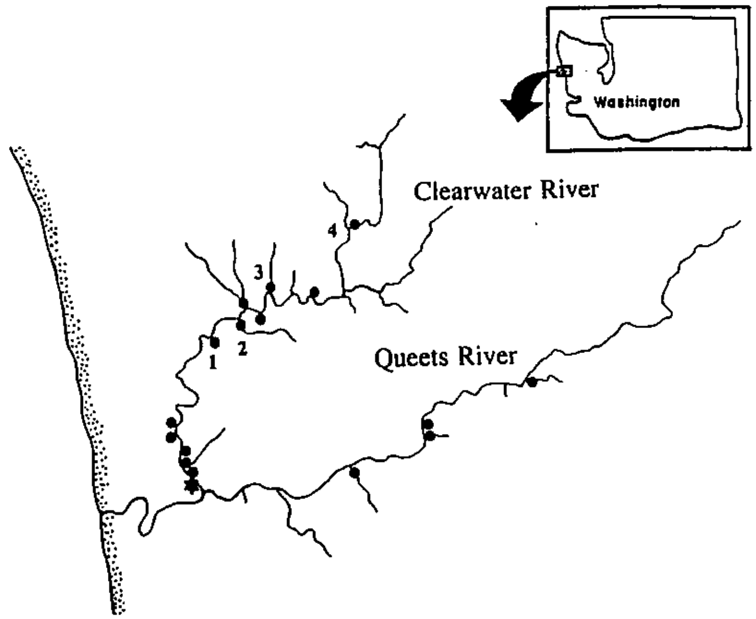

FIGURE 1. Stream and pond smolt traps (circles) and the Clearwater River mainstem mark-recapture site (star) in the Queets River system, Washington. Locations: (1) Paradise Pond, (2) Shale Creek, (3) Christmas Creek, and (4) Snahapish River.

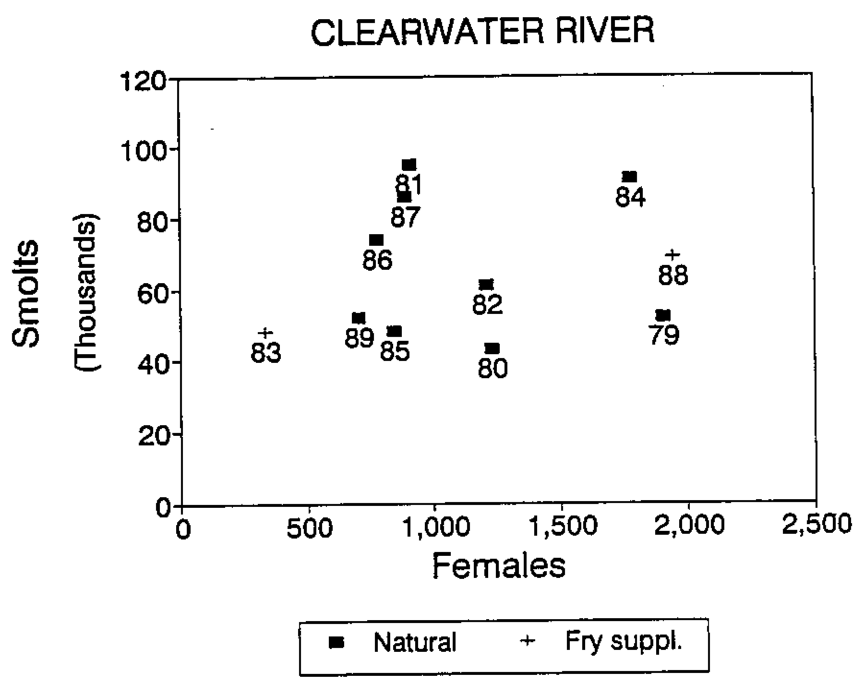

FIGURE 2. Relationship between spawning escapement and smolt yield for coho salmon in the Clearwater River system. Brood years for natural (square) and fry supplemented (plus) production are denoted.

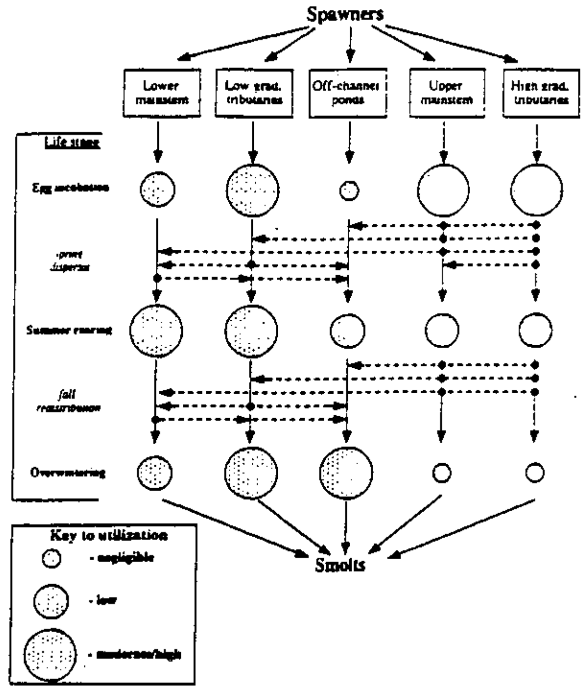

FIGURE 3. Utilization of different areas of the Clearwater River system by life stage for coho salmon. Circle size reflects the relative amounts of production attributed to each area. Dashed lines show movements of fish from one area (dot) to another area (arrow).

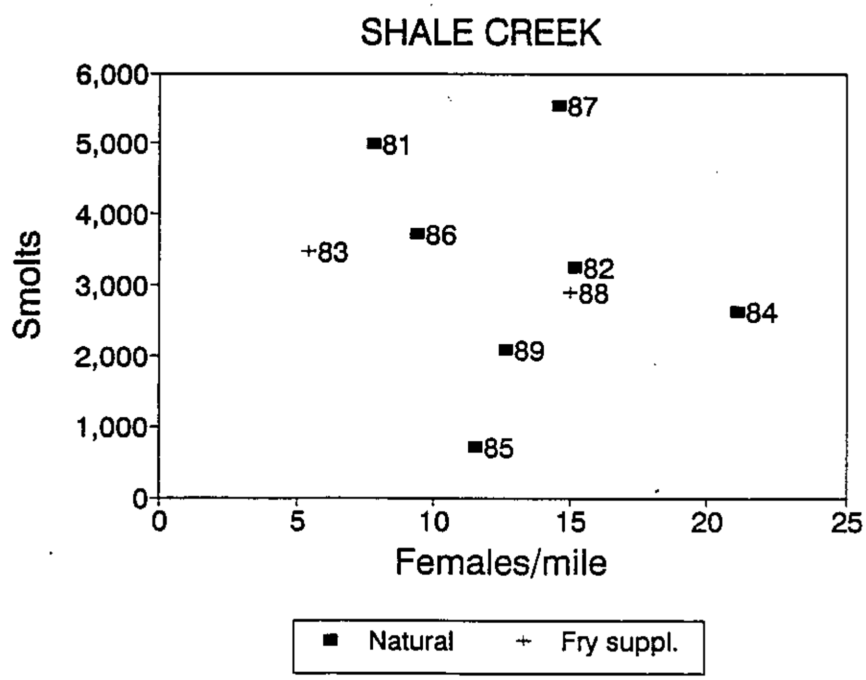

FIGURE 4. Relationship between spawning escapement and smolt yield in Shale Creek, a low gradient tributary to the Clearwater River. Brood years for natural (square) and fry supplemented (plus) production are denoted.

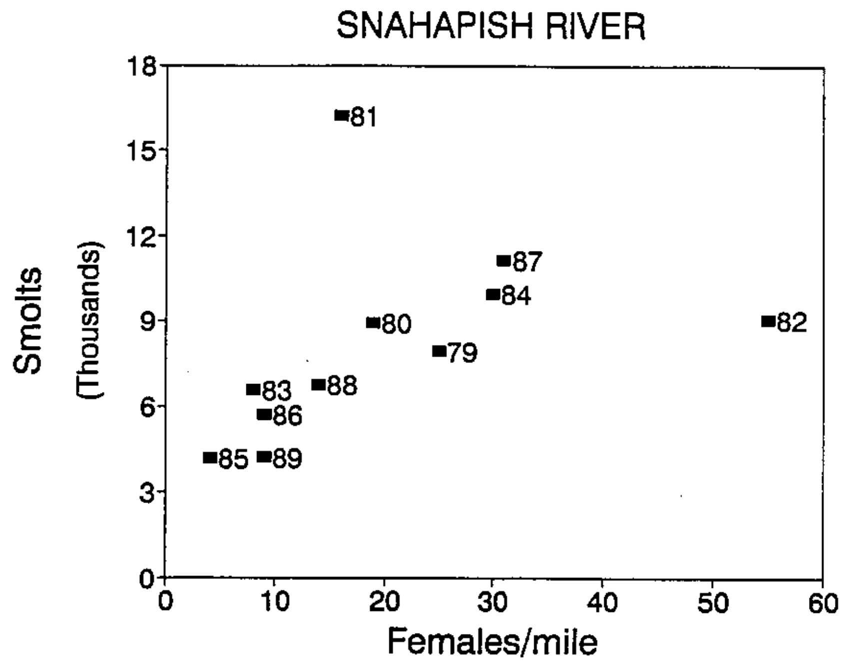

FIGURE 5. Relationship between spawning escapement and smolt yield in Snahapish River, a low gradient tributary to the Clearwater River. Brood years are denoted. No fry supplementation occurred in this stream.

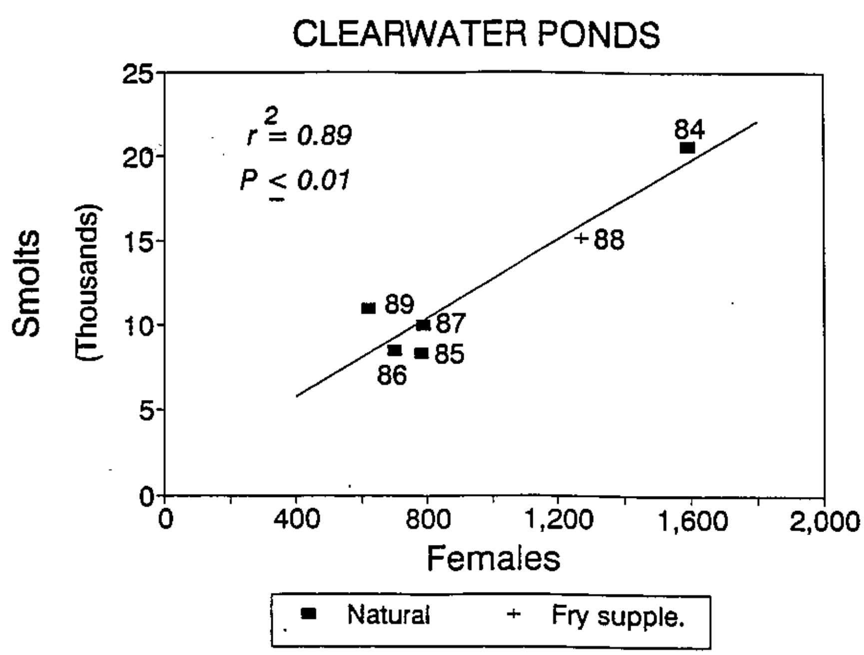

FIGURE 6. Relationship between spawning escapement and the combined smolt yield from five off-channel ponds in the Clearwater River system. Spawning escapements shown are those estimated to have occurred in areas upstream of the ponds. Brood years for natural (square) and fry supplemented (plus) production are denoted. Supplemented fry were not released directly into the ponds (see text).

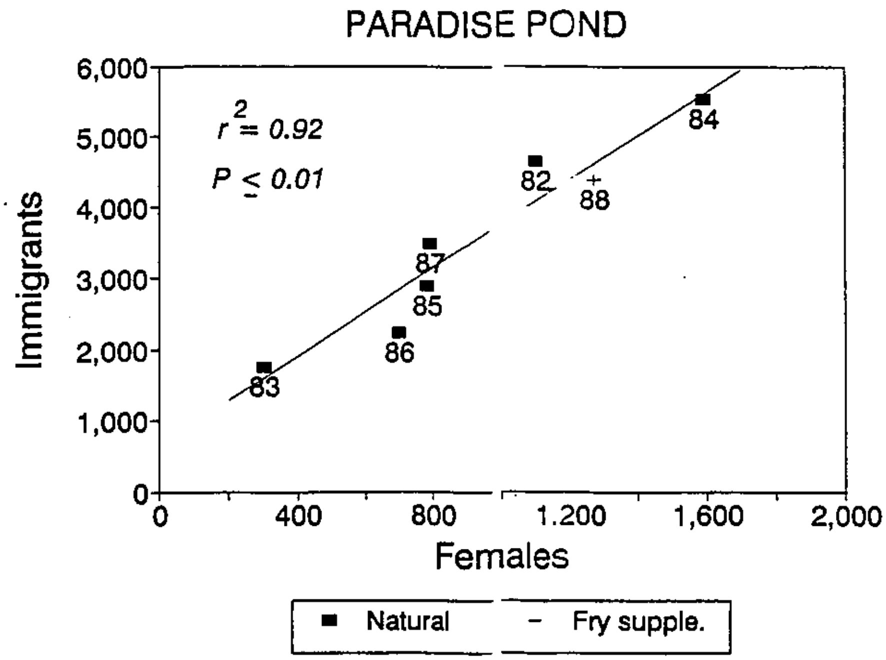

FIGURE 7. Relationship between spawning escapement and the number of coho fingerlings immigrating into Paradise Pond during fall. Spawning escapements shown are those estimated to have occurred in areas upstream of the pond. Brood years for natural (square) and fry supplemented (plus) production are denoted. A few immigrants from brood year 1983 were survivors of small scale fry supplementation that occurred in the Clearwater subbasin.

TABLE 1. Summary of brood stock collection, fry outplants and smolt releases of Queets River coho salmon for brood years 1983 to 1989. The isolation of viral hemorrhagic septicemia in December, 1989 prevented a smolt release for brood year 1988, a majority of the smolt release for brood year 1989 and a fry outplant for brood year 1989.

	Brood Year						
	1983	1984	1985	1986	1987	1988	1989
Females spawned	0	100	56	109	141	982	392
Eggs collected	0	320,000	180,000	329,300	399,000	2,796,500	1,058,300
Fry released	123,700[1]	0	0	0	0	2,002,600[2]	--
Smolts released	0	64,600	137,000	208,000	279,000	--	34,000

[1] Fry were of Soleduck Hatchery stock; fry ranged in size from 2.1 to 3.2 g.

[2] Fry ranged in size from 0.9 to 1.6 g.

TABLE 2. Survival rates to smolt stage of marked coho salmon fry and contribution to smolt yield for fry outplanted in the Clearwater River subbasin for brood years 1983 and 1988. Contribution of supplemented fish to smolt yield includes the survivors of fry that were outplanted into other areas of the Clearwater subbasin, which subsequently moved into the stream prior to smolt emigration, and unmarked fry. Survival rates of unmarked fry were determined from survival rates for representative marked groups adjusted for differential survival between marked and unmarked fish (see text for details).

		Survival %		Smolts	
Location	No. Fry Released	Stream[1]	Clearwater subbasin	Supple. %	Natural + Supple.
BROOD YEAR 1983					
Low Gradient Stream					
Shale Creek	119,542	1.9	2.7	66	3,500
High Gradient Stream					
Manor Creek[2]	4,189	10.8	10.8	100	530
Clearwater subbasin	123,731	--	--	8	48,000
BROOD YEAR 1988					
Low Gradient Streams					
Shale Creek	20,000	2.5	7.3	33	2,900
Hunt Creek	18,000	3.2	3.9	90	630
Bull Creek	12,400	1.5	2.1	48	910
High Gradient Streams					
Christmas Creek	98,000	0.6	2.4	81	1,400
Manor Creek[2]	16,800	1.0	2.4	100	320
Clearwater River Mainstem					
Lower Mainstem	125,500	--	1.4	--	--
Upper Mainstem	126,460	--	1.4	--	--
Clearwater subbasin[3]	619,660	--	--	35	68,800

[1] Estimated fry to smolt survival of marked fry that remained in release streams.

[2] Fry were stocked above an anadromous barrier in Manor Creek. Fry were outplanted at 1.3 fry per m^2 in brood year 1983 and 5.0 fry per m^2 in brood year 1988.

[3] Includes 202,500 unmarked fry outplanted into three additional tributaries of the Clearwater subbasin.