A Review of the Literature on the Feasibility of Outplanting Hatchery-Reared Fry, Fingerling, and Smolts, with Emphasis on Coho and Spring Chinook Salmon Outplanting in the Puget Sound Region

Robert Wunderlich

July, 1982

U.S. Fish and Wildlife Service
Fisheries Assistance Office
Olympia, Washington

DRAFT

INTRODUCTION

In 1980, the Olympia Fisheries Assistance Office (FAO) of the U.S. Fish and Wildlife Service drafted a plan for restoring Puget Sound spring chinook salmon populations. A major goal of this plan was to develop a broodstock program at Quilcene National Fish Hatchery (NFH) for use in re-establishing spring chinook into suitable habitat in the Puget Sound region. This broodstock program was initiated in 1981 at Quilcene NFH with the transfer of approximately 500,000 Nooksack X Cowlitz eggs from the Cowlitz State Hatchery. As an operational planning aid, this review is an attempt to develop general recommendations pertaining to the feasibility of eventually outplanting spring chinook fry, fingerling, and smolts from Quilcene NFH into natural rearing habitat in the Puget Sound region. Additionally, because rearing of both spring chinook and coho to smolt size may create rearing space problems at this facility, the feasibility of outplanting coho salmon fry, fingerling, and smolts was examined as well. This review therefore focuses on spring chinook and coho, and the feasibility of outplanting these fish in the Puget Sound area.

Feasibility, as used in this paper, implies that off-station plants of these fish will not adversely impact other salmonid stocks to any significant degree, and that outplanted fish will survive and contribute to fisheries on a level comparable to equivalent on-station releases.)

This review first describes the principal considerations in outplanting, including suitability of the release site in terms of habitat requirements and species interactions, followed by reported survival and straying of outplanted hatchery fish. The review concludes with an assessment of the feasibility of the proposed outplanting, general outplanting recommendations for spring chinook and coho applicable to Quilcene NFH, and outstanding information needs on this subject at the present time.

OUTPLANTING CONSIDERATIONS

Release Site Suitability

The capacity of any release site to provide suitable rearing habitat for pre-smolt and smolt outplants is dependent in large part on the availability of food and space, as these factors are important regulators of salmonid populations in streams (Chapman, 1966). Implicit in these basic requirements is the availability of all essential habitat components for the juvenile freshwater life history stages of each species, as well as lack of adverse interaction with other resident or introduced species.

For Puget Sound spring chinook, the essential components of freshwater juvenile habitat are poorly understood. The length of juvenile residence of this fish in Puget Sound has not been documented, although some evidence indicates a subyearling emigration occurs at least in the Nooksack River system (Wunderlich et al., 1982), in contrast to the typical yearling emigration observed in the Columbia drainage (Wahle et al., 1981). However, Seiler et al. (1981) encountered fair numbers of yearling-sized chinook in an intensive downstream trapping project on the south fork of the Skykomish River of Puget Sound, although no mention of race was suggested..

Available early life history data relative to spring chinook habitat requirements is largely derived from studies of Columbia River stocks in Idaho, and may therefore have only limited applicability to Puget Sound due to possible major differences in emigration timing. At any rate, in Idaho streams, recently-emergent spring chinook fry utilize shallow, nearshore waters and gradually shift to faster, deeper waters as they grow (Chapman and Bjornn, 1969). Similar utilization of shoreline habitat was noted in wild spring chinook fry collections in the Nooksack River drainage (Wunderlich et al., 1982) and fall chinook collections in Oregon (Reimers, 1971) and British Columbia (Lister and Genoe, 1970). Chinook fry initially "hide" among shoreline gravels shortly after emergence (Reimers, 1971), possibly to avoid predators and to reduce downstream displacement during freshets (Bustard and Narver, 1975). Idaho investigators (Chapman and Bjornn, 1969; Everest and Chapman, 1972) also observed that spring chinook fry utilize only a small home area during daylight, and at night settle to the bottom, usually after moving inshore a short distance (less than 5m).

Spring chinook fingerlings in Idaho streams exhibit a downstream movement in early fall, overwintering in larger streams and often living beneath rocks in the winter, burying themselves in pockets beneath rubble. This behavior is apparently a function of water temperature, with most fish hiding in substrate at temperatures below 4.4 to 5.5 C. Availability of winter cover, especially large rocks, is therefore very important in holding these overwintering fish (Chapman, 1966; Chapman and Bjornn, 1969).

In contrast, essential components of juvenile coho habitat in Puget Sound drainages are comparatively well understood. Juvenile coho typically reside one year in freshwater, although downstream migration of subyearling fish has been observed possibly resulting from territorial displacement, discussed below (Chapman, 1962). Recently emergent coho fry occupy stream margin areas in association with bank cover and, with increased size, move into habitat of progressively higher velocity and greater depth in the very same manner as chinook fry (Lister and Genoe, 1970). Larger coho juveniles, however, are typically associated with pools or glides with back eddies, abundant overhanging vegetation, and undercut roots of streambank vegetation (Pearson et al., 1970; Ruggles, 1966). Dense shade is avoided, however (Ruggles, 1966).

Overwintering habitat of yearling coho typically includes combinations of the above cover types. A series of unused beaver ponds provided important overwintering habitat for coho in Carnation Creek on the west coast of Vancouver Island, with a survival rate estimated to be twice that of the entire system (Bustard and Narver, 1975). Peterson (1980) also suggested that spring ponds on the Olympic Peninsula were important winter refuge areas for coho fingerlings displaced by freshets. Coho apparently do not overwinter in stream substrate noted above for spring chinook, however (Hartman, 1965).

Mundie (1969) observed that an ideal food channel for maximum coho smolt production would have the following features: shallow depth (7-60 cm), fairly swift mid-stream flows (60 cm/sec), numerous marginal back eddies, narrow width (3-6m), copious overhanging mixed vegetation, and banks permitting hiding spaces. Additionally, occasional freshets, without extremes in flow, should occur to remove accumulated silt.

Of the factors limiting coho production in Puget Sound drainages, rearing area is considered the principal one (Zillges, 1977), and rearing area is controlled primarily by summertime low flows (Flint, 1977). Coho escapement goals for Puget Sound are presently based on areal or lineal estimates of available summer rearing habitat and reported estimates of smolt production potential by stream type (Chapman, 1965; Lister and Walker, 1966), weighted by variances in watershed productivity due to glacial input (less), fluctuating water levels (less), and beaver dams and marsh areas (greater) (Zillges, 1977).

In addition to habitat components, species interactions, in the form of competition and predation, significantly influence the suitability of a release site for outplants. Coho have been more intensively studied than spring chinook in this regard. The bulk of spring chinook investigations are again apparently limited to the upper Columbia drainage in Idaho.

The high degree of intraspecific competition among juvenile coho in holding territories and maintaining food-gathering sites in the stream environment has important implications for outplanting. Such competition is probably continuous from emergence of fry until the fall months, and it results in displacement and downstream movement of smaller coho (Chapman, 1962). Displaced individuals probably die if suitable habitat is not located downstream (Otto and McInerney, 1970; Royal, 1972). A food-space regulator therefore operates during late spring to early fall in coho streams, which places a limit on coho production in a given stream area (Mason, 1976). Such a food-space regulator relates to rearing area limits in Puget Sound streams, noted above. Stocking coho in excess of carrying capacity therefore results in no greater production of coho, and may be detrimental to existing coho stocks by stimulating outmigration of smaller fish, and slowing growth and reducing survival of resident fish (Mason, 1976). For these reasons, coho outplants are usually restricted to grossly underseeded or barren areas (Tim Flint, Wash. Dept. Fisheries, pers. comm.; Oregon Dept. of Fish and Wildlife, 1981), and scatter planting is preferable to mass planting in a given stream area (Salo and Bayliff, 1958; Smirnov, 1960).

Studies of competitive interaction of coho with other juvenile salmonids suggest that adverse effects on trout and steelhead, at least, are minimized through slightly different microhabitat preferences of the respective species. Pearson et al. (1970) examined coho rearing capacity in nineteen northern Oregon streams over a five-year period and concluded among other things that coho population fluctuations probably did not significantly affect coexisting trout populations. Similarly, Burns (1971) observed that coho introductions in one northern California stream increased the total carrying capacity of the coho/trout complex in the stream through more efficient utilization of all available habitat. In Penny Creek on the Olympic Peninsula, plants of swim-up coho fry above an anadromous barrier had no detectable impact on density, growth, and condition of resident cutthroat trout (Washington State Game Department, 1979 and Tom Johnson, Snow Creek Research Project Leader, pers. comm.).

Although coho/spring chinook competitive interaction has not been specifically addressed, studies of competition in juvenile coho and fall chinook have been conducted in the Big Qualicum River of British Columbia and the Sixes River of Oregon. In the Big Qualicum study, Lister and Genoe (1970) determined that differences in time of emergence and size resulted in a high degree of spatial separation of the two species, even though their habitat requirements during the first three months of life were very similar. Fall chinook emerged about a month earlier than coho, were larger upon emergence, and grew at a faster rate. The chinook therefore preferred higher velocity locations than coho during their juvenile freshwater residence and interspecific competition for food and space was not apparent. On the other hand, Stein (1971), in the Sixes River investigation, observed that coho and fall chinook emerged at the same time in this river and exhibited similar size and growth rate, but warmer mainstem river temperatures caused most coho to move into cooler tributary streams and spatial separation was maintained in this manner. In concurrent laboratory trough studies where spatial separation was not maintained, coho dominated food-gathering sites and outgrew chinook. These findings led Stein to conclude that introduction of hatchery coho in the Sixes River could reduce chinook numbers, as coho were present in relatively low numbers and spatial separation was apparently only marginally maintained by temperature-related behavior in this system.

Available information on spring chinook competitive interaction concerns only chinook/steelhead studies in the upper Columbia drainage. Studies of Idaho streams indicated that subyearling spring chinook and steelhead utilized the same physical space, ~~space,~~ but competitive interaction was again minimized by differing times of spawning and fry emergence resulting in different size groups of presmolts with different habitat preferences (Chapman and Bjornn, 1969; Everest and Chapman, 1972). In this way, size-related differences in habitat selection prevented competitive interactions of subyearlings. This may explain at least in part the increased total fish production (tissue elaboration) and yield of migrants observed in Idaho's upper Lemhi drainage when spring chinook and steelhead fry were both introduced than when only steelhead fry were released, although steelhead trout production itself was somewhat reduced when spring chinook were present in study streams (Bjornn, 1978). Overwintering spring chinook and steelhead apparently also utilize similar instream cover without serious adverse interaction (Chapman and Bjornn, 1969).

In addition to competitive interaction, intra- and inter-specific predation is a significant consideration in evaluating the suitability of a release site. A recent review of the subject by Cardwell and Fresh (1979) indicated that predation upon salmonid juveniles can be severe, and it is perhaps greatest in freshwater where juveniles are concentrated and most vulnerable due to small size and extended residence. In a study of spring chinook carrying capacity in Knapp Creek in central Idaho, Sekulich (1980) observed that when predators were removed prior to stocking age 0 spring chinook, 49.4% of stocked fish remained in study sites versus only 14.8% without predator removal (primarily larger salmonids). In general, Sekulich noted that hatchery plants survived better with lower predator densities and were perhaps more influenced by predators than their wild counterparts.

Additionally, depending on size relationships, spring chinook as well as coho may themselves be important predators, and due to this fact Cardwell and Fresh (1979) recommended against planting "incompatible combinations of salmonid predators (e.g., coho, spring chinook) and salmonid prey (e.g., fall chinook, chum) in streams." Partially for this reason, coho and spring chinook smolt plants in Hood Canal streams of Puget Sound are presently limited by time and location to reduce possible predation on pink and chum fry.

Survival and Straying

Studies of the survival of off-station plants indicate that, in general, survival increases with increasing size of fish stocked, although a number of factors such as density, distribution, fish health, and transport to release site play a role. Further, available estimates of total survival (catch plus escapement) may be influenced by the accuracy of escapement-to-release-site estimates, as well as degree of straying.

Region-specific data on off-station plants deal mainly with coho, although limited coded wire tag data on spring chinook plants are also available. Early studies of stream survival (survival to smolt) and total survival associated with varying densities of coho plants into Minter Creek over a 16-year period indicated generally increasing survival trends with increased hatchery rearing (Salo and Bayliff, 1958). Table 1 summarizes this phenomenon. Salo and Bayliff also observed that the adverse effects of overstocking coho in Minter Creek were less pronounced with increasing size of fish stocked. Preliminary data from more recent studies of coho fry plants in Puget Sound streams also suggest greater survival of fed versus unfed fry plants (Tim Flint, Wash. Dept. Fisheries, pers. comm). No comparable pre-smolt stocking data for spring chinook are available for Puget Sound.

Coded wire tag studies of off-station coho smolt plants suggest that survival is comparable to on-station releases, but results are somewhat variable. Total survival of coho smolt outplants from Quinault NFH into the Humptulips and Queets Rivers averaged 0.51%, which was similar to on-station coho smolt releases during the same period (Hiss et al., 1982). Outplants of coho

Table 1. Stream survival and total survival of coho for various periods of hatchery rearing prior to planting in Minter Creek, southern Puget Sound. Source: Salo and Bayliff, 1958.

Hatchery Rearing (months)	Stream Survival	Total Survival
2 1/2-4	10%	-
3	-	< 0.5%
6	20%	0.6%
8-9	40%	1.3 - 1.9%
12	70%	1.1%
14	87%	< 0.8%

smolts from Soleduc and Simpson State Hatcheries survived at a substantially lower rate than control group releases, but disease problems may have caused the reduced survival observed in transplant groups (Fuss and Rasch, 1981). Dungness State Hatchery outplants of coho smolts into Snow Creek and the Little Quilcene River resulted in survival rates of 5.8% and 0.4%, respectively, but the latter group may have been subjected to hauling stress (Bagatell et al., 1980). An extensive study by Flint (1981) of coho smolt plantings in nine Puget Sound streams indicated that total survival for all release groups was apparently acceptable and ranged from 3 to 10%. As part of the latter study, test hauling of Dungeness coho smolts for 1 to 3 hours resulted in no adverse effects on contribution compared to control groups (in two out of four cases, survival was actually greater in hauled versus unhauled groups).

Coded wire tagging studies of spring chinook outplants in Puget Sound have indicated highly variable survival rates, although data are limited and control releases were not made for comparison. Two groups of Soleduc Hatchery yearlings (Dungeness stock) survived at 0.40% and 11.46% after release in the Elwha and Dungeness Rivers, respectively (Bagatell et al., 1981). A yearling (11.4/lb) and subyearling (92.0/lb) plant of native Skykomish stock into the south fork of the Skykomish river resulted in higher survival for the yearling group (3.6%) versus the subyearling group (0.18%), suggesting that subyearling releases are not optimal for good survival (Fuss et al., 1981). One group of yearling Cowlitz stock outplanted into the Dosewallips River survived at a moderate rate of 0.86% (Source of data: Dick O'Connor, Wash. Dept. Fisheries).

Fry, fingerling, and smolt outplants of spring chinook into Idaho's Clearwater River drainage have resulted in high survival, according to Horner and Bjornn (1981). Pre-smolt and smolt outplants were initiated in 1971 after migration barriers were removed in a portion of the drainage historically used by spring chinook. Sources of eggs and fish used in outplanting were largely indigenous to that locale, although some transplants originated from Cowlitz State Hatchery. Adult returns during the last 15 years reportedly have increased, with returns approaching 5,000 adults in recent years despite increasing passage losses at Snake and Columbia River dams.

Survival of the progeny of hatchery outplants may be questionable in some situations, however. Available data from ongoing studies of Kalama River steelhead (Chilcote et al., 1981) suggest that offspring of first generation hatchery fish spawning in the wild may have a lower survival rate from egg to age 0 life stage. Additionally, steelhead smolt data from this suggest a lower survival rate throughout the entire freshwater life cycle of the hatchery fish progeny, but these findings are still somewhat tentative as genetic markers used in the study may have influenced survival rate. The observed greater mortality among hatchery offspring may also have been due to the early timing of the hatchery stock, which made it more susceptible than the native run to redd scouring during winter floods (Mark Chilcote, Kalama Research Project Leader, pers. comm.).

Potential straying of off-station plants may affect the success of the planting effort, depending on the objectives of the program and concerns over potential genetic and disease impacts to other stocks. Lister et al. (1981) recently reviewed over 400 sources of information relative to straying of salmon and steelhead outplants, and concluded that no definitive guidelines could be made with respect to the amount and type of imprinting required to assure a high rate of homing to an off-station release site, although length of exposure to the release location is apparently a factor in some cases. The authors, however, made the following generalizations relative to straying of off-station releases of Pacific salmonids:

1. Straying due to release location. Within system, releases downstream of the rearing (hatchery) site strayed less than releases above the rearing site. Out of system, releases which were a greater distance from the rearing site strayed less.

2. Straying due to life stage at release. Higher straying occurred with smolt plants versus pre-smolt plants, indicating length of exposure to the release stream can influence the strength of imprinting.

3. Straying due to hybridization. No available evidence suggested that hybrids strayed more than non-hybrid outplants.

4. Straying due to saltwater release. If rearing and release sites were widely separated, little exposure to freshwater was necessary for homing to the release site.

A recent study by Flint (1981) evaluated degree of straying from nine off-station releases of coho smolts in the Puget Sound area. Release streams, nearby streams, and hatchery facilities in the release area were surveyed for mark recoveries. Little or no straying was observed from Dungeness State Hatchery plants into Little Quilcene R., Dewatto Creek, and Rockybrook Creek of Hood Canal. By way of comparison, the highest incidence of straying (70%) resulted from plants of Puyallup State Hatchery fish into South Prarie Creek, which is above the rearing site in the same watershed. This study is perhaps the most relevant work available on this subject for the Puget Sound area at the present time.

DISCUSSION AND RECOMMENDATIONS

Review of the foregoing literature suggests that outplanting coho and spring chinook fry, fingerling, and smolts from Quilcene NFH in the Puget Sound region is probably feasible, as defined. However, outplanting of either species into natural rearing habitat should occur only within certain constraints, pending development of additional relevant information on behavior and habitat requirements, as well as careful consideration of planting objectives and existing management practices in the proposed area of release.

The factors involved in determining a suitable release location and size and time of planting are numerous and inter-related. Information presented herein indicates that smolt releases will likely result in greater survival than pre-smolt releases, although the potential for predation and straying may also be greater. Smolt releases will return to the release location which, if located in a lower river reach, may not contain suitable spawning habitat. On the other hand, fry or fingerling releases require the availability of underutilized rearing habitat, and the latter requires an assessment of carrying capacity and a determination of appropriate planting density. Additionally, potential predators and competitors must be considered at the release site. Potential genetic contamination of native stocks must be considered in both pre-smolt and smolt outplanting.

In view of the above, the following should be considered in developing specific plans for outplanting coho or spring chinook from Quilcene NFH in the Puget Sound region:

1. Underutilized habitat must be available for fry or fingerling outplants. Essential habitat components for each species should be present insofar as is known. For spring chinook, watersheds which historically contained these fish in abundance are likely candidates (e.g., Dosewallips and Skokomish systems of Hood Canal), pending development of needed early life history information for Puget Sound spring chinook. For coho, barren or grossly underseeded streams due to migrational barriers, overfishing, or previous habitat degradation, or hatchery streams, are possible candidates for outplanting.

2. Appropriate planting densities should be determined to avoid overstocking. For spring chinook, carrying capacities presently need to be developed. For coho, maximum potential smolt production of a proposed release location may be estimated from available summer low flow rearing area and published rearing potential (Zillges, 1977), adjusted for assumed survival from pre-smolt to smolt stage, as appropriate.

3. Potential competitor/predator problems should be avoided. Size relationships of coho, chinook, and possibly steelhead should be considered to reduce possible overlapping of habitat preferences with resulting competition in early life history stages. Time or space separation should be employed to avoid obvious predator/prey conflicts.

4. Existing Puget Sound management plans should be considered. The Hood Canal Management Plan, for example, emphasizes natural coho production, except in Quilcene Bay tributaries. Coho smolt plants would therefore be inappropriate in most Hood Canal drainages at the present time.

5. Transportation to the release site should minimize stress through maintenanace of adequate water quality in the delivery vehicle, water tempering at the release site, and attention to other technical details during transport and release.

6. Potential straying due to life stage at release and release location should be considered as it relates to enhancement objectives and possible genetic or disease impacts to other stocks .

A number of data needs are apparent at this time relative to outplanting spring chinook and coho in the Puget Sound region. Accordingly, development of the following information will facilitate specific planning for spring chinook and coho outplanting from Quilcene NFH:

Spring Chinook Data Needs

1. Early life history information, including emigration timing and habitat requirements for the remaining viable stocks of Puget Sound spring chinook, is needed. Carrying capacity and appropriate planting density for pre-smolt outplants in the Puget Sound region should be developed concurrently.

2. Survival and contribution data for various time/size outplants compared to control releases are needed. Survival data should include escapement-to-release site estimates, and determination of the viability of hatchery offspring through coded-wire tagging and/or genetic marking, if possible.

3. An examination of potential competition and predation associated with spring chinook outplants due to size, timing, or other factors at potential release locations is needed.

4. A survey of potential outplanting locations in Puget Sound, with the considerations noted earlier as part of the selection criteria, should be conducted.

Coho Data Needs

1. Continued investigation and refinement of off-station contribution and survival data, particularly for pre-smolt outplants, with appropriate control releases for comparison should be pursued.

2. A determination of potential genetic impacts on native coho stocks due to outplanting is needed.

3. Evaluation of potential competition between coho fry plants and resident spring chinook stocks is needed. Specifically, coho fry outplanting in the upper Nooksack basin, which is utilized by native spring chinook fry, should be examined for potentially serious competitive conflicts.

4. A survey of potential outplanting locations in Puget Sound should be conducted, incorporating the considerations noted above in the selection criteria.

LITERATURE CITED

Bagatell, C., R. Rasch, and C. Johnson. 1980. A review of the experiments with the 1970 and 1971 brood coho salmon (Oncorhynchus kisutch) from thirteen Washington Department of Fisheries hatcheries. Progress Report No. 94. Wash. Dept. of Fisheries. 155 pp.

Bagatell, C., H. Fuss, T. Rasch, and C. Johnson. 1981. A review of the experiments with the 1971 brood summer/fall chinook salmon (Onchorynchus tshawytscha) released from Washington Department of Fisheries hatcheries. Progress Report No. 139. Wash. Dept. of Fisheries. 67 pp.

Bjornn, T. C. 1978. Survival, production, and yield of trout and chinook salmon in the Lemhi River, Idaho. Idaho Coop. Fish. Res. Unit. Fed. Aid Project F-49-R. 57 pp.

Burns, J. 1971. The carrying capacity for juvenile salmonids in some northern California streams. Calif. Fish and Game 57 (1) : 44-57.

Bustard, D. R. and D.W. Narver. 1975. Aspects of the winter ecology of juvenile coho salmon (Oncorhynchus kisutch) and steelhead trout (Salmo gairdneri). J. Fish. Res. Bd. Can. 32:667-680.

Cardwell, R. D. and K. L. Fresh. 1979. Predation upon juvenile salmon. Draft No. 8. Wash. Dept. of Fisheries. 21 pp.

Chapman, D. 1962. Aggressive behavior in juvenile coho salmon as a cause of emigration. J. Fish. Res. Bd. Can. 19:1047-1080.

Chapman, D. 1965. Net production of coho salmon in three oregon streams. Trahs. Amer. Fish. Soc. 94: 40-52.

Chapman, D. 1966. Food and space as regulators of salmonid populations in streams. Amer. Nat. 100:345-357.

Chapman, D. (ed.) 1979. Salmon and steelhead in western Washington: an ecologicial report. Prepared for use in United States, et al. v. State of Washington et al. Civil No. 9213-II, United States District Court, Western District of Washington.

Chapman, D. and T. Bjornn. 1969. Distribution of salmonids in streams, with special reference to food and feeding. p. 153-176. In T. G. Northcote (ed.), Symposium on Salmon and Trout in Streams. H.R. MacMillan Lectures in Fisheries, Univ. B.C., Vancouver.

Chilcote, M. W., S.A. Leider, and J. J. Loch. 1981. Kalama River salmonid studies. 1981 Progress Report. Wash. State Game Dept. NMFS Contract #81-ABH-00025. 93 pp.

Edmundson, E., F. Everest, and D. Chapman. 1968. Permanence of station in juvenile chinook salmon and steelhead trout. J. Fish. Res. Bd. Can. 25:1453-1464.

Everest, F. and D. Chapman. 1972. Habitat selection and spatial interaction by juvenile chinook salmon and steelhead trout in two Idaho strams. J. Fish. Res. Bd. Can. 29:91-100.

Flint, T. 1977. Juvenile coho population estimates determined by electrofishing in 12 Puget Sound streams August-October 1976. Progress Report No. 32. Wash. Dept. Fisheries. 18 pp.

Flint, T. 1981. Contribution of off-station coho yearling plants. In Review of the Effects of Enhancement Strategies on the Homing, Straying and Survival of Pacific Salmonids by D.B. Lister, D.A. Hickey and I. Wallace. Vol. II, App. 10. D. B. Lister and Assoc. Ltd., Vancouver, B. C.

Fuss, H. and T. Rasch. 1981. A review of the 1974 brood coho salmon (Oncorhynchus kisutch) experiments from Puget Sound and coastal Washington Department of Fisheries hatcheries. Progress Report No. 147. Wash. Dept. of Fisheries. 217 pp.

Fuss, H., T. Rasch, and C. Johnson. 1981. A review of the experiments with the 1972 brood spring and fall chinook salmon (Oncorhynchus tshawytscha) released from eighteen Washington Department of Fisheries hatcheries. Prog. Rep. No. 143. Wash. Dept. of Fisheries. 63 pp. plus appendices.

Hartman, G. 1965. The role of behavior in the ecology and interaction of underyearling coho salmon (Oncorhychus kisutch) and steelhead trout (Salmo gairdneri). J. Fish Res. Bd. Can. 22:1035-1081.

Hiss, J. M., M. L. Paiya, and R. S. Boomer. 1982. Quinault National Fish Hatchery salmon and steelhead coded-wire tagging results. Olympia Fish. Assist. Office. U.S. Fish and Wildlife Service (in preparation).

Horner, N. and T. Bjornn. 1981. Status of upper Columbia and Snake River spring chinook salmon in relation to the Endangered Species Act. Idaho Cooperative Fishery Research Unit. University of Idaho, Moscow. 63 pp.

Lister, D. B. and H. Genoe. 1970. Stream habitat utilization by cohabiting underyearlings of chinook (Oncorhynchus tshawytscha) and coho (O. kisutch) salmon in the Big Qualicum River, British Columbia. J. Fish. Res. Bd. Can. 27:1215-1224.

Lister, D. B., D. G. Hickey, and I. Wallace. 1981. Review of the effects of enhancement strategies on the homing, straying and survival of Pacific salmonids. Vols. I & II. Report prepared for Canadian Department of Fisheries and Oceans. D. B. Lister & Associates Ltd., Vancouver, B.C. 51 pp. plus appendices.

Lister, D. and C. Walker. 1966. The effect of flow control on freshwater survival of chum, coho, and chinook salmon in the Big Qualicum River. Can. Fish Cult. 37: 3-25.

Mason, J. 1974. Movements of fish populations in Lymn Creek, Vancouver Island: a summary from weir operations during 1971 and 1972, including comments on species life histories. Technical Report No. 483. Canadian Fisheries and Marine Service. 35 pp.

Mason, J. 1976. Response of underyearling coho salmon to supplemental feeding in a natural stream. J. Wildl. Manage. 40:775-788.

Mason, J. and D. Chapman. 1965. Significance of early emergence, environmental rearing capacity, and behavioral ecology of juvenile coho salmon in stream channels. J. Fish. Res. Bd. Can. 22:173-190.

Mundie, J. 1969. Ecological implications on the diet of juvenile coho in streams. p. 135-152. In T.G. Northcote (ed.), Symposium on Salmon and Trout in Streams. H. R. MacMillan Lectures in Fisheries, Univ. B.C., Vancouver.

Oregon Dept. of Fish & Wildlife. 1981. Comprehensive plan for production and management of Oregon's anadromous salmon and trout. Part II. Coho Salmon Plan.

Otto, R. and J.McInerney. 1970. Development of salinity preference in pre-smolt coho salmon, Oncorhynchus kisutch. J. Fish. Res. Bd. Can. 27:793-800.

Pearson, L., K. Conover, and R. Sams. 1970. Factors affecting the natural rearing of juvenile coho salmon during the summer flow season. Unpub. Manuscript. Oregon Fish Commision. 63 pp.

Peterson, N. P. 1980. The role of spring ponds in the winter ecology and natural production of coho salmon (Oncorhynchus kisutch) on the Olympic Peninsula, Washington. M. S. Thesis. Univ. of Wash. 96 pp.

Reimers, P. 1971. The length of residence of juvenile fall chinook salmon in Sixes River, Oregon. Ph. D. Thesis. Oregon State Univ. 99 pp.

Royal, L. A. 1972. An examination of the anadromous trout program of the Washington State Game Department. Wash. State Game Dept. 176 pp.

Ruggles, C. 1966. Depth and velocity as a factor in stream rearing and production of juvenile coho salmon. Can. Fish. Cult. 38:37-53.

Salo, E. and W. Bayliff. 1958. Artificial and natural production of silver salmon, Oncorhynchus kisutch, at Minter Creek, Washington. Research Bulletin No. 4. Wash. Dept. Fisheries. 76 pp.

Seiler, D., S. Neuhauser, and M. Ackley. 1981. Upstream/downstream salmonid trapping project, 1977-1980. Prog. Report No. 144. Wash. Dept. Fisheries. 197 pp.

Sekulich, P. 1980. The carrying capacity of infertile forest streams for rearing juvenile chinook salmon. Ph.D. Thesis. Univ. of Idaho. 156 pp.

Smirnov, A. 1960. The characteristics of the biology of reproduction and development of the coho - Oncorhynchus kisutch (Walbaum). Vestnik Moskovskovo Universiteta Series 6:9-19. Fisheries Research Board Translation Series No. 287.

Stein, R. A. 1971. Social interaction between juvenile coho and fall chinook salmon in Sixes River, Oregon. M.S. Thesis. Oregon State Univ. 50 pp.

Wahle, R., E. Chaney, and R. Pearson. 1981. Areal distribution of marked Columbia River basin spring chinook salmon recovered in fisheries and at parent hatcheries. Marine Fish. Rev. 43:1-9.

Washington State Game Department. 1979. Penney Creek coho planting study. In Progress report for the period ending December 31, 1979, Cooperative agreement 14-16-0001-5776 FS and 14-16-0001-6345 IFC. U.S. Fish and Wildlife Service and Washington State Game Department.

Wunderlich, R., J. Meyer, and R. Boomer. 1982. Nooksack River juvenile spring chinook salmon investigations. Olympia Fisheries Assist. Office. U.S. Fish and Wildlife Service. 61 pp.

Zillges, G. 1977. Methodology for determining Puget Sound coho escapement goals, escapement estimates, 1977 pre-season run size prediction and in-season run assessment. Tech. Rep. No. 28. Wash. Dept. Fisheries. 65 pp.