Part Three
Appendix

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Appendix Report 3.1
Specific Criteria Guiding Supplementation and Reintroduction Program Operations

Following are specific criteria that should be used for all summer chum supplementation and reintroduction programs under this plan. These criteria refine general criteria for conducting supplementation programs that were previously provided in Part Two of the plan. Application of these specific criteria will help minimize adverse ecological and genetic effects to natural summer chum populations. The criteria also define practical rearing and release procedures that have been demonstrated to be of greatest benefit to healthy chum fry production in the hatchery environment and the survival of released fish to adulthood.

1. Donor Stock Selection and Collection Methods

Donor stocks selected for supplementation programs will be derived from the indigenous summer chum population within the targeted watershed. For reintroductions, donor stocks selected will be those that are geographically nearest the targeted stream, and that show the greatest similarity in genetic lineage, life history patterns, and ecology to the extirpated population. Donor stocks selected for reintroduction will only be used at one location.

The acceptable minimum and maximum broodstock collection levels, based on the abundance of the donor population, are indicated in Table 3.2 in Part Two of the preceding plan. As noted in the table, in the case of severely depressed populations and for supplementation programs only, if the entire population is less than 100 fish, all of the population may be taken for use as broodstock in the supplementation program. In this case, a minimum of 25 pairs should be targeted for the supplementation program.

Donor broodstock may be available for use if escapement to the donor stream will: 1) meet an identified spawner escapement objective, 2) provide the egg-take needs of any on-going supplementation program operating in the donor stream; and 3) provide a minimum of 25 pairs required for a reintroduction program.

Summer chum should be collected from donor populations across the breadth of the freshwater return (mid August through October 15 - to preclude egg takes of fall chum), and at weekly levels proportional to average escapement timings for the returning population. Methods used to collect broodstock are as follows:

- fish weirs permitted via Hydraulic Project Approval, Shoreline Act, and SEPA processes positioned at or very near the downstream limit of spawning within the donor/targeted watershed;
- snorkel survey/block seine collection within freshwater fish migration and holding areas; and
- selective fishery (e.g. beach seine) removal in the targeted stream, or in extreme terminal marine areas immediately adjacent to the mouth of the target stream.

Collected fish will be transferred as soon as possible from trap holding boxes, adult holding tubes or net-pens to hatchery holding and spawning facilities. During all capture, holding and handling phases, fish will be netted, handled, and transferred with the utmost care, ensuring that harm to the fish, including the duration that chum are out of water, is maintained to a minimum.

2. Spawning/Mating Protocols

The two main goals for the breeding of summer chum broodstock are for every adult to contribute, and for the genetic contribution from each fish to the population to be as equal as possible (Phelps 1993). These goals include the desire to minimize loss of alleles and to maintain the heterozygosity present in the existing wild populations. In meeting these goals, spawning protocols will be applied that ensure that contributing broodstocks are representative of wild stock diversity. Fish spawned will represent the breadth of the summer chum return, in timing and proportion by timing. The entire August through October span of the return will be represented in spawning, to the extent feasible.

Mating schemes used in all summer chum supplementation programs have the objective of incorporating at least 1:1 male-female spawning ratios. Given the preceding goals, and the parameters regarding run timing representation, all matings will be randomized with respect to fish age, size, and phenotypic traits. Intentional selection of any particular trait in the use of spawners, including age, size, and other morphological characters, will be avoided.

For populations scheduled for supplementation that are small (25 pairs or less), the desire to ensure that every adult used in the program will contribute to matings, rather than equalized contribution, will be prioritized. Matings for such populations on any given spawning day will be conducted by dividing each female's eggs into as many aliquots as there are ripe males. Each aliquot from one female will then be fertilized with a different male. Fertilization would be accomplished by adding sperm from one male, mixing the eggs thoroughly for 30 seconds, and then adding sperm from a different back-up male prior to water hardening the eggs. For these small donor populations, males can be held after spawning for use on more than one spawning day, as long as the number of times each male is used is noted, and that newly captured or ripe males are incorporated. The use of sperm extenders and cryopreservation are also viable options for maintaining sperm for crosses made for small populations. Kapuscinski and Miller (1993) provides further protocols that should be followed in devising mating schemes for depressed populations when either males or females are in short supply.

3. Incubation and Rearing Protocols

Incubation and rearing protocols proposed in this plan are designed to produce the most summer chum fry in the shortest amount of time in the hatchery, while producing fish that are as genetically and ecologically similar as possible to the founding natural population. Fish health maintenance, disinfection, and fish disease treatment procedures set forth in the Washington Co-manager's Salmonid Disease Control Policy will be applied throughout the husbandry process to maintain high fish quality and to minimize mortalities. Environmental conditions during incubation and propagation, including water temperature (daily and seasonal regimes), water quality, and photoperiod will be equivalent to, or closely simulate, conditions found in the natural environment for the founding population. To help meet this objective, the location of incubation and rearing will be within the same watershed, and in close proximity to the planned summer chum release site. To the extent feasible, achieving this latter goal will also involve the use of water for incubation and rearing sourced from the founding river for supplementation programs. Husbandry strategies will include use of low incubation and rearing densities, as set forth in the following sections.

The following survival rate objectives for each life stage will be applied to all programs. These rates will be used as criteria for measuring the effectiveness of each program.

Chum Life Stage	% Survival by Life Stage	Cum. % Survival from Green Egg
Green egg to eye-up	90.0 %	90.0 %
Eye-up to Swim-up	99.5 %	89.5 %
Swim-up to release	95.0 %	85.0 %

a) Production Levels

Annual summer chum fry production levels for supplementation and reintroduction programs will be determined through estimation of the number of smolts required to meet historical spawning levels upon return as adults. Criteria that will be used to derive the desired annual production levels are provided in section 3.2.2.3 of the preceding plan.

Appendix Table 3.1.1 presents desired, initial planting levels derived from the aforementioned production and survival criteria for summer chum streams that are supplemented, or have the potential to be supplemented or receive fish for reintroductions, in the future. These planting levels are minimums, based on 1974-78 average escapement estimates, and may be adjusted if research shows that survival rates are different than those assumed. It is recognized that there is likely some "critical mass" for a chum fry release that must be achieved for the propagated population to exhibit adult returns at desired survival rates. This concept is based on the premise that small releases (e.g. <15,000) of fish of 1 gram size may be more subject to loss through happenstance or natural mortality than larger release groups (e.g. 100,000). In studies of chum fry predation on Big Beef Creek, Fresh and Schroder (1987) corroborated this premise, finding that the number of fry eaten by predators increased asymptotically with the number of fry released. Chum fry were most vulnerable at low abundance and least vulnerable when abundance was high. The decreased vulnerability at high release levels generally resulted from predator satiation or from time constraints arising from

capturing and swallowing prey. The upper end of the release ranges indicated in Appendix Table 3.1.1 are therefore recommended.

Appendix Table 3.1.1 Recommended initial annual summer chum fry supplementation program production levels needed to produce adult returns equal to historical (1974-78) average run sizes. [1]

Watershed	1974-78 Average Run Sizes[2]	Fed Fry Survival Rate[3]	Annual Fry Supplementation Level (1000s)[4]
Big Quilcene R.	3,152	0.81 - 1.63 %	193 - 389
Little Quilcene R.	1,418	0.81 - 1.63 %	87 - 175
Dosewallips R.	3,355	0.81 - 1.63 %	206 - 414
Duckabush R.	3,855	0.81 - 1.63 %	236 - 476
Hamma Hamma R.	6,503	0.81 - 1.63 %	399 - 803
Dewatto R.	1,549	0.81 - 1.63 %	95 - 191
Tahuya R.	5,732	0.81 - 1.63 %	352 - 708
Lilliwaup R.	3,132	0.81 - 1.63 %	192 - 387
Anderson Ck.	700	0.81 - 1.63 %	43 - 86
Big Beef Ck.	839	0.81 - 1.63 %	51 - 104
Union River	700	0.81 - 1.63 %	43 - 86
Salmon Ck.	859	0.81 - 1.63 %	53 - 106
Snow Ck.	720	0.81 - 1.63 %	44 - 89
Chimacum Ck.	700	0.81 - 1.63 %	43 - 86
Jimmycomelately Ck.	700	0.81 - 1.63 %	43 - 86

Notes:

1 The number of adult summer chum recruiting to Puget Sound (all age classes) as a result of escapement and spawning by adult fish produced through the supplementation program may be estimated as follows, assuming a 20% fisheries exploitation rate: multiply the expected number of female spawners ((run size*0.8)/2) by 2,500 (average fecundity), then by 10% (estimated wild survival green egg to smolt), and then by 1% (estimated survival of wild smolts to adult return).

2 Run size estimates over 700 represent the 1974-78 average run size for each stream or stock. For populations averaging less than 700 for the 1974-78 period, the run size level is listed as 700. This 700 fish standard is derived from criteria set forth in Allendorf et al. (1997) which defines the minimum population size needed for a stock to *not* be at moderate risk of extinction (use N_e of 2,500/3.6 years (average chum generational length) = 700 fish). These levels are provisional, and will be changed when the parties to this plan have developed agreed escapement and run size objectives to be applied to recover the populations. The run size figures presented here are used to derive recommended planting levels.

3 Survival rate range presented is based on the estimated average percent survival rate to Puget Sound for Hoodsport Hatchery fall chum (1.63 % from Fuss and Hopley 1991) and, to be conservative, ½ that average, assuming expected, smaller summer chum release levels and potentially lower productivity for summer chum.

4 Desired annual production levels were derived by dividing the 1974-78 average run size by each of the potential survival rates. These fry release ranges assume a wild fish contribution of "0". To account for wild production, annual, estimated wild adult returns each year may be subtracted from base year average run sizes to refine the number of hatchery-origin fry needed.

b) Incubation

Eggs and alevins will be incubated under density, substrate, light, temperature, and oxygen conditions that simulate the natural intragravel environment (Kapuscinski and Miller 1993), or

exceed its quality, to the extent feasible. Acceptable incubator types for use in proposed supplementation programs are listed and prioritized as follows: Heath-style trays, incubation baskets in rearing troughs, remote site incubators (RSIs). Incubation trays, baskets, and screens will be loaded at conservative, low densities that produce the highest survivals and quality to the fry stage. Green eggs, eyed eggs, and alevins will be incubated under dark or low-light conditions to minimize stress and decrease energy expenditure, minimizing the incidence of yolk malformation, decreased survival, and smaller fry at swim-up. Artificial substrate will be used during incubation and hatching of eyed eggs to mimic the natural environment. Shocking and removal of dead eggs will be accomplished when the eggs portray a well developed, strongly pigmented eye (after the accumulation of approximately 550 to 600 temperature units).

Heath trays will be loaded at a maximum density of 4,500-5,000 green eggs, and 3,500-4,000 eyed eggs. Flows into Heath stacks will be maintained at 4 gallons per minute to provide the most suitable environment to reduce bacterial loads (T. Kane and D. Zajac, USFWS, pers. comm., Feb. 1998).

Although it is desirable to match incubation water temperatures with ambient stream temperatures to match wild chum emergence timing, water supplies for RSIs shall be spring or well-sourced to minimize the risk of losses due to flooding, or from egg/alevin suffocation caused by excess siltation. Eyed eggs are the preferred life stage for incubation and fifty-five gallon RSIs are the preferred version used for summer chum propagation. RSIs may be operated with up to five or six incubation screens, with each screen loaded with up to 15,000 eggs (K. Dimmitt, WDFW, pers. comm. April, 1998). Loading at these densities will lead to the incubation of up to 90,000 eyed eggs per RSI. Flows into RSIs will be maintained between 9 - 12 gpm during operation. Bio-saddles will be used to harbor incubating alevins. Bio-saddles should be loaded to occupy a minimum depth of 15" of the bottom portion of the RSI to safely hold alevins resulting from the recommended eyed egg loading densities.

c) Rearing

The objective of all summer chum supplementation programs shall be the production and release of 1 gram average size smolts for release during March (Hood Canal) or April (Strait of Juan de Fuca) each year. It is recognized that summer chum naturally have little tendency to rear in freshwater, out-migrating seaward immediately after swim-up (see Tynan 1997). Therefore, rather than mimicking natural rearing behavior, summer chum fry and fingerlings will be reared in freshwater under density, light, temperature, hydraulic conditions, and oxygen conditions, and with diets and at feeding rates, that promote the production of healthy smolts that will exhibit the highest possible survival rates to return.

1. **Densities** - Hatchery rearing densities will be those that yield the highest number survivals. Given that the actual identification of such densities is not likely, given current available data, the following conservative “standard” and “maximum” pond loading densities will be applied in all proposed supplementation programs to promote the release of healthy, viable fish (S. Evans and T. Tynan, WDFW, pers. comm. Feb. 1998).

	Pounds fish/gpm inflow		Pounds fish/ft3 rearing volume	
Chum size	Standard	Max.	Standard	Max.
Swim-up	<1.0	1.5	0.5	0.75
1200-600/lb	1.0	2.5	1.0	2.0
600-400/lb	1.5	3.0	1.0	2.0

Summer chum reared in marine net-pens should be held at densities no greater than 0.3 pounds of fish per cubic foot of net-pen space, assuming the pens are sited in an area with moderate tidal exchange (see marine net-pen guidelines from Washington Department of Ecology for siting criteria as per NPDES Permit requirements).

Accurate estimates of the biomass of the rearing population are needed to allow for the calculation of pond densities. Weight samples should be taken on a bi-weekly basis to determine average fish size to be applied to inventoried numbers of fish in deriving biomass estimates.

2. **Light conditions** - Light conditions during rearing will be maintained to mimic ambient seasonal photo-periods. Summer chum will be propagated outdoors to the extent feasible to comply with this objective.

3. **Hydraulic conditions** - Velocities and flow patterns in freshwater rearing ponds will be maintained at levels that provide for beneficial exercise of rearing fish, promoting prolonged swimming ability while optimizing feed distribution, removal of fish waste, and water exchange. The occurrence of "dead spots" in rearing ponds should be minimized to help avoid gill problems and to maintain fish health.

4. **Oxygen conditions** - Oxygen levels in rearing ponds will be maintained at levels that are optimal for juvenile salmon growth and survival. Oxygen concentrations at inflow should be at or near saturation (11-13 ppm). Effluent oxygen concentrations should be no less than 9 ppm.

5. **Fish diets and feeding rates** - Diets used in supplementation programs will be high quality, commercial grade, fish meal-based moist or semi-moist feeds currently available to Pacific Northwest salmon hatchery operations. Observed food conversion rates should be <1.3 for the diets used and as achieved through the methods used to apply the feed. Diets selected will have a minimum percentage of fines to minimize the risk of gill irritation and disease. Feed sizes will be matched to fish size as follows:

Chum size	Feed Size
Swim-up	#1
1200-600/lb	#1 or #2, 1/32"
600-350/lb	#2 or 1/32"

Feed will be applied at rates that balance the need to minimize the duration of rearing, the maintenance of acceptable feeding efficiencies, and the desire to achieve targeted release sizes

by the March or April release dates, with the need to prevent gill irritation and disease through over-application of feed. At all times, daily feeding rates will be maintained below 0.10 pounds feed per gallon per minute pond inflow per day to minimize gill irritation, and to guard against bacterial gill disease out-breaks. Accurate population size inventories, and average fish size estimates, are needed in order to evaluate whether this maximum feeding rate limitation is being met. Direct human contact with fish during feeding will also be minimized to reduce association of humans with food and to allow for more natural development of predator avoidance behavior in rearing fish. Feed shall not be supplied to fish that will be fin-clipped or tagged beginning one day in advance of the planned handling date.

6. **Fish health maintenance, monitoring, and pre-release evaluation** - Rearing ponds and screens will be maintained in a manner that ensures a hygienic environment for summer chum production. Mortalities should be removed and enumerated at least daily to allow for monitoring of population size and fish health status. Rearing units should be cleaned frequently to remove accumulated fish waste and uneaten feed. Troughs and tanks used for rearing should be cleaned daily, and raceways should be cleaned three times per week in a manner that does not re-suspend wastes into the water column where rearing fish may be adversely affected. The frequency of rearing unit cleaning should be balanced, however, with the need to minimize disturbance to the fish.

   All summer chum will be reared under the guidance of certified fish health personnel and in accordance with the Co-Manager's Salmonid Disease Control Policy (NWIFC and WDFW 1998). Fish will be monitored daily during rearing for signs of disease, through observations of feeding behavior and monitoring of daily mortality trends. Preferred and maximum pond loading and feeding parameters will be adhered to at all times. Summer chum will be examined by a fish pathologist within three weeks prior to release to determine fish health status.

7. **Differentially mark all hatchery release groups** - To allow for estimation of spawning ground return rates, contribution rates to extreme terminal area fisheries, and (through mass marking) differentiation from natural-origin fish, summer chum produced each year in supplementation programs under this plan will be marked. All, or an appropriate proportion of each hatchery population (as determined by population size and the proportion identified as needed to form valid estimates of survival and contribution), will be marked through thermal banding (otoliths), removal of the adipose fin, application of a coded wire tag, or application of a coded wire tag-adipose clip combination. Marking will occur at the appropriate time during incubation (thermal marking), or at least one week in advance of release (adipose fin removal or CWT application).

d) Release Strategies

Fish liberation strategies will be designed to release fry of a size and condition, and at a time that will maximize freshwater exodus rates, survival from the river to the estuary, survival during estuarine migration, and survival to adult return.

1. **Life stage and size at release** - WDFW fall chum hatcheries in Hood Canal have achieved high fry to adult survival rates (0.62 - 3.23 % - Fuss and Hopley (1991)) through the release of fed

chum fry of an average size of 1 gram (400- 450/pound), equating to an average length of 50-52 mm. This size at release was set as a target by WDFW beginning in the late 1970s to mimic chum production programs in Japan (Hager 1980), which have demonstrated smolt to adult survival rates for one gram chum fry released from hatcheries in Hokkaido of 2.0 - 3.1 % (1965-1981 brood year data from Kaeriyama 1989). Since 1993, summer chum fry of approximately one gram average size have been consistently released through the supplementation program at Quilcene National Fish Hatchery with similar, high apparent adult return rates.

Further rationale for the release of fed fry is the increased freshwater survival rates accrued through the release of larger chum. Fresh et al. (1980) demonstrated a freshwater survival rate of 46.2 % for unfed fry releases (39.2 mm average fork length) at Big Beef Creek, compared to 84.7 % survival for fed fry releases (55.7 mm average fork length).

Therefore, although wild summer chum migrate to seawater immediately after swim-up, the production of unfed fry will *not* be the preferred method for supplementing regional summer chum populations under this plan. Consistent with the desire to quickly boost the abundance of populations in the region in a minimal number of generations, all summer chum supplementation and reintroduction programs will endeavor to release fed fry of an average size of one gram to maximize survival rates. The minimal duration of intervention into the natural summer chum life cycle attached with producing a fed fry, and the survival rate advantage of fed fry over unfed fry, support the strategy of releasing one gram summer chum. Achievement of a one gram average release size should be attained by the normal out-migration period for wild summer chum fry in Hood Canal (March) and the eastern Strait of Juan de Fuca (April).

2. **Location of release** - Summer chum fry produced through this plan will be released into target drainages only after a significant level of incubation, rearing, and therefore, acclimation, within the target watershed. On-site incubation of eyed eggs, or transfer of unfed fry, for rearing of fry at the site of release to one gram size, are the preferred supplementation strategies. Transfers of chum fry reared at a hatchery facility for direct release into another drainage will not be allowed, due to uncertainty regarding homing ability of transferred fish, and the likely, diminished survivability for chum fry transferred and released in this manner. Acclimation ponds may be used at the desired release location to receive unfed fry incubated and hatched at another facility, if the duration of rearing time at the acclimation site is deemed sufficient to foster imprinting. Exceptions to this limitation may be made for hatchery facilities located on watersheds that share the same discrete estuary with a stream desired for planting (e.g. Big and Little Quilcene rivers; Salmon and Snow creeks). Research has shown that natural stray rates between such geographically proximate streams can be substantial (Tallman and Healey 1994). The co-managers consider streams sharing the same immediate estuary as harboring the same stock under this plan, and straying of supplementation-origin fish between such streams is therefore not a concern.

   Summer chum fry released from freshwater locations should be liberated as close to the estuary as possible to allow for rapid exodus from freshwater, and to minimize the number of fish that may be lost to predation (Fresh et al. 1980). Freshwater survival for Big Beef Creek chum was estimated to be 73.7 % for fry released at river kilometer 2.3 and 48.2 % for fry released at river

kilometer 10.0, showing that increased exposure to predators decreases survival (Fresh et al. 1980). The choice of a liberation site in the lower part of the watershed should be balanced against the desire to distribute returning spawners across all available summer chum spawning areas upon return. Given that summer chum in the region generally spawn in the lower mile of each watershed, attempts should be made to liberate chum fry no further upstream than the lowest identified spawning locations. Chum fry liberations made further upstream should be mitigated by releasing the fish at night and when flows are amenable for flushing the fish from the system quickly.

Seawater net-pens used for additional rearing of summer chum should be located within the immediate estuary of the watershed where freshwater rearing occurred. Location of net-pens proximate to the desired return stream will minimize the risk of straying to other areas.

3. **Transport methods** - Methods and equipment used to transport summer chum from freshwater rearing sites to acclimation sites or seawater net-pens shall be designed to minimize harm to the fish. Where feasible, fish should be transferred from ponds to transport trucks using sanctuary nets to retain fish in water. Transport tanks should be supplied with oxygen at prescribed flow rates, providing oxygen concentrations within the tank of at least 10 ppm during transport.. Water in tanks should be equal in temperature to the source rearing pond, and fish should be loaded into the tanks at no greater than 0.285 pounds of fish per gallon of water (Ashcraft 1982). Tank lids should be secured with quick-release latches to firmly secure the lid during transport. Fish should be released from transport tanks into acclimation ponds or net-pens through flex hoses connected to the tanks outlet, avoiding additional dip-netting of fish from tanks.

4. **Timing of release** - Summer chum will be released from freshwater facilities during the seasonal period that coincides with the natural out-migration time for wild summer chum in the regions. The schedule of wild fry emigration can be considered the optimum release period because its evolution is geared to maximizing survival (Cardwell and Fresh 1979; Fresh et al. 1980 quoting Kobayashi 1976). For Hood Canal, summer chum fry are estimated to migrate into the estuary and out of Hood Canal between the first week in February and the third week in April (Tynan 1997). For eastern Strait streams, summer chum should be liberated from freshwater facilities or net-pens between the first week in February and the fourth week in May (Tynan 1997). To take advantage of increases in estuarine productivity promoted by spring-time increases in photoperiod, summer chum releases should be timed to occur towards the mid-point of the periods mentioned.

   Within Hood Canal, it is also desirable to release summer chum prior to the advent of hatchery fall chum releases from the southwest Hood Canal facilities. Releasing summer chum prior to the fall chum liberations will decrease the risk of competitive interactions that have the potential to decrease summer chum survival. This strategy may also provide summer chum with a competitive advantage by providing the populations first opportunity for food resources in the Canal. Beginning in 1998, WDFW has implemented a policy to release fall chum fed fry from all southwest Hood Canal hatcheries after the first week in April. Therefore, summer chum should be released prior to the end of March to minimize interactions with hatchery-origin fall chum.

5. **Methods of release** - Methods for liberating fish from freshwater facilities will be employed that maximize the rate of fish exodus from the stream to seawater, and that minimize the risk of predation on the released population. In all cases, hatchery releases should be made between dusk and midnight, mimicking the natural estuarine arrival period for wild chum fry, reducing the likelihood for significant fish and avian predation, and facilitating time for adaptation of the fish to the new estuarine environment (Fresh et al. 1980; Salo 1991). Fresh et al. (1980) found that chum fry released from Big Beef Creek had freshwater survival rates of 93.7 % when released near mid-night, compared to a survival rate of 71.8 % for chum fry released at mid-day (1100 hours).

   Fish should be released directly into the main stream channel to take advantage of the negative rheotactic response inherent in egressing chum, fostering rapid downstream exodus in the main, deepest water course. Summer chum releases should be made so that the arrival of the fish in the estuary coincides with a high tide, or with a high tide that is just beginning to ebb, to decrease the risk of stranding, and minimize the length of confinement in the freshwater channel during downstream migration.

   Fresh et al. (1980) demonstrated that mortality for newly released chum fry was inversely density-dependent (depensatory). Freshwater survival for Big Beef Creek chum was shown to increase non-linearly with number of fry released, ranging from 40.3 % when 517 fry were released, to 91.5 % when 50,155 were released (Fresh et al. 1980). Chum fry should therefore be released en masse to swamp predators in freshwater and in the immediate estuary, and to promote schooling of the fish when in seawater. Schooling has been shown to reduce predation losses (Cardwell and Fresh 1979, citing Brock and Riffenburg 1960 and Major 1978). This release strategy is chosen over practices that incorporate temporal and spatial variation (similar to wild fry emigration, which can span a one month period) because of the optimized time of release (during the period when natural fish have been successful in the estuary), and the survival advantage that may be imparted by predator swamping. The fact that rearing in freshwater as called for through this supplementation plan is not a natural trait for wild summer chum is also considered. The desire in this instance is to maximize survival for the release group, and not to mimic natural egression characteristics exhibited by unfed, wild fry.

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Appendix Report 3.2
Existing Summer Chum Supplementation and Reintroduction Projects

Supplementation has been applied as a strategy to help recover summer chum populations in Hood Canal and the eastern Strait of Juan de Fuca since 1992. Programs initiated that year included Big Quilcene River, Lilliwaup Creek, and Salmon Creek supplementation projects. A supplementation project on Hamma Hamma River began in 1987. Beginning in 1996, the regional population recovery strategy evolved to the point where reintroductions of fish into streams where summer chum populations had been extirpated became feasible. Transfers of progeny from appropriate broodstocks to reintroduce summer chum into Chimacum Creek and Big Beef Creek began with brood year 1996. All of these summer chum recovery programs are on-going.

Descriptions of each existing supplementation and reintroduction program, including program objectives, broodstock collection figures, fry production data, and operating procedures and objectives are presented below. These programs were instituted prior to the full development and completion of this plan. The following descriptions of existing programs may therefore include objectives, methods, and strategies that are not fully consistent with the tenets of the plan. However, the intent is to adjust existing programs to comply with the objectives, risk minimization methods, and strategies presented in the preceding document.

1. Hood Canal Region

a) Big Quilcene River - Quilcene National Fish Hatchery Program

Summer chum salmon were first reared at Quilcene National Fish Hatchery (QNFH) from 1912 to 1937. During this time, eggs were collected from broodstock in various rivers of western Hood Canal - Big and Little Quilcene rivers, Dosewallips River, and Duckabush River. Eggs were hatched and fry raised at QNFH, with fry released into the Big Quilcene River or into the river where the broodstock originated. The QNFH summer chum salmon program was terminated in 1938 when the lower Quilcene River was "modified" and the fish could no longer make it back to the hatchery. By the late 1980s and early 1990s the adult returns to the Big Quilcene River were at very low numbers (less than 50 annually 1989-91), and with on-going habitat threats to the population, there was a possibility that summer chum could go extinct in this system. Thus it became a primary candidate for supplementation.

A supplementation program was started in 1992, to take advantage of the last relatively strong summer chum cycle year return. About half of the 400 returning adults were taken for brood stock purposes and delivered to QNFH. A portion of the 1992 brood year release was tagged to determine the success of supplementation and the timing and distribution of the stock. Since most chum

salmon do not migrate as far up the river as the hatchery, the 1992 brood stock were obtained from the Quilcene Bay coho fishery and through collecting in the lower river.

With the first brood stock collection, various objectives and provisions were identified. Through an evolving joint interim agreement of the co-managers, the following guidelines have been developed: 1) the summer chum program would attempt to rebuild the run from the existing low level while preserving its genetic character; 2) the program would continue for a maximum of three generations (12 years); 3) brood stock would be captured in the Big Quilcene River and in Quilcene Bay; 4) at least 50% of adults returning to Quilcene Bay in any given year will be allowed to escape to spawn naturally; 5) egg takes will be representative of the timing and duration of the run, 6) brood stock would be sampled for GSI, scales, other biological characters, and for disease assessment purposes; 7) the release goal would be 400,000 maximum; 8) resulting hatchery fry would be released into the Big Quilcene River at this time; 9) hatchery practices would comply with the co-manager's disease policy; and 10) genetic considerations would be addressed prior to the use of this broodstock for any reintroductions.

Supplementation efforts have continued. Data for each brood year are summarized in Appendix Table 3.2.1. Over 2,500 fish have been spawned at QNFH and 1.98 million fry have been released into the Big Quilcene River since the inception of the program. This program may have been immensely important in 1993 and 1996, when portions of the Big Quilcene River containing summer chum redds were illegally bulldozed. The extent of mortality as a result of this activity in 1993 was estimated to be about 29% of the natural spawner escapement to the Big Quilcene River (Uehara 1994). Given that the adult escapement in 1993 was only 89 chum, the mortality level that year was significant.

Appendix Table 3.2.1. Quilcene National Fish Hatchery summer chum supplementation program data - 1992-97[1]

Brood Year	Broodstock Removals/Swim-ins			Natural Spawners	Percent Removed	# Fed Fry Released	Release Size (gms)	Release Date
	# Males	# Females	Total					
1992	225	186	411	320	56.2	216,441	1.05	4/13/93
1993	19	17	36	97	27.1	24,784	1.46	3/30/94
1994	169	178	347	349	50.1	343,550	1.06	3/27/95
1995	228	256	484	4,029	10.7	441,167	1.06	3/27/96
1996	438	333	771	8,479	8.3	612,598[1]	1.34	4/10/97
1997	274	261	535	7,339	6.8	340,744	1.62	4/2, 15/98
1998	315	232	547	2,244	19.6	343,530	1.28	3/8, 3/22, 4/2/99

[1] Figures do not include 204,000 fish in 1997, ~112,000 fish in 1998, ~200,000 fish in 1999 of QNFH origin produced at Big Beef Creek.

The supplementation program at QNFH appears to have been particularly effective in assisting achievement of stock recovery objectives, significantly increasing spawner abundances in the Big Quilcene River. Observed, large adult return levels in 1995-98 relative to previous years have coincided with the timing of expected returns for supplemented brood years (e.g. three year old chum from the first supplementation brood year of 1992 returned in 1995) The increased Big Quilcene

River returns in recent years are likely due to a combination of factors, including harvest management actions and perhaps a change in ocean conditions that may have increased marine survival. But the escapements appear proportionally much higher than for non-supplemented streams within the same time period. Average returns to the Big Quilcene River over the 1994-98 period increased 4,724 % over the recent period (1988-93) preceding the supplementation program (4,488 fish average for 1994-98 compared with 95 fish average in 1988-93). This high percent change in average escapements observed for the Big Quilcene River compares to 1,002 % and 480 % increases recorded for adjacent non-supplemented stocks in the Dosewallips and Duckabush rivers, respectively, over the same two periods. It is apparent that the Big Quilcene supplementation project has contributed to the increased returns observed for this stock.

b) Lilliwaup Creek Cooperative Program Long Live The Kings Enhancement Group

In 1992, WDFW initiated a cooperative fish rearing project with the Hood Canal Salmon Enhancement Group (HCSEG) to rebuild the indigenous summer chum salmon population in Lilliwaup Creek, a western Hood Canal tributary, through a hatchery supplementation program. This effort was conceived as part of a multi-agency initiative to increase the abundance of summer chum in response to declines in the population observed in the 1980s, and the designation of west-side Hood Canal summer chum the stock as critically depressed through the 1992 Salmon and Steelhead Stock Inventory (WDF et al. 1993) process. In 1994, Long Live the Kings (LLTK) assumed primary responsibility for this project. The project is now managed by LLTK through a contractual agreement with WDFW, and is partially funded through a contract administered by USFWS. LLTK consults with the HCSEG on the operation of the project.

The goal of the Lilliwaup project is to contribute to the restoration of a healthy, naturally self-sustaining population of Lilliwaup Creek summer chum salmon which maintains the genetic characteristics of the native stock. The identified objective was to implement an effective short-term recovery effort to counteract the current risk of extinction due to the small population size.

Supplementation guidelines for the project dictate that recovery planning for the watershed be consistent with a draft version of the Hood Canal and Strait of Juan de Fuca Summer Chum Conservation Plan (January 17, 1997). The contribution of the Lilliwaup project and its potential expansion would be determined through this comprehensive planning process. Production level goals, broodstock collection methods, and rearing densities would be set in accordance with principles identified in the conservation plan. Appendix Table 3.2.2 summarizes summer chum fry production in Lilliwaup Creek for 1992-97.

Through joint agreement between WDFW, the PNPTC tribes, and LLTK, the following guidelines were initially applied for the operation of the project: 1) the program would attempt to rebuild the run from the existing low level while preserving its genetic character; 2) the program would continue for a maximum of three generations (12 years); 3) all brood stock would be captured in the Lilliwaup River; 4) at least 50% of adults returning to river in any given year will be allowed to spawn naturally; 5) egg take will be represented throughout the timing duration of the run, and the spawning ratio shall be one female to one male; 6) brood stock would be sampled for GSI, scales, other biological characters, and for disease assessment; 7) a maximum of 25 pairs will be used in this

project, unless otherwise agreed by the parties; 8) resulting hatchery fry would be released as 1 gram fish into the Lilliwaup River; 9) beginning in 1997, all fry released will be otolith marked; 10) in order to prevent the spread of viral pathogens, sampling of all broodstock will follow appropriate actions mandated by the Co-managers' Salmonid Disease Control Policy, and accepted fish health practices and monitoring will be applied during rearing; and 11) the project will include a monitoring and evaluation program. Due to recent, extremely depressed abundance levels, the co-managers determined in 1998 that all returning fish may be used for the supplementation program as an emergency measure.

Appendix Table 3.2.2 Lilliwaup Creek summer chum supplementation program data - 1992-97

Brood Year	Broodstock Removals/Swim-ins			Natural Spawners	Percent Removed	# Fed Fry Released	Release Size (gms)	Release Date
	# Males	# Females	Total					
1992	-	-	18	90	16.7	20,000	0.4	March
1993	-	-	10	72	12.2	12,000	fed	March
1994	-	-	12	105	10.3	15,000	fed	March
1995	-	-	0	79	0	0	-	-
1996	-	-	12	40	23.1	15,000	fed	March
1997	11	7	18	10	64.3	14,200	1.0	March 1

Through 1997, there have been difficulties in collecting adequate numbers of brood stock. Attempts in this regard have been complicated by the lack of a fish collection weir, low overall summer chum return levels, and the presence of pink salmon in the same stream areas as summer chum. In 1998, WDFW was able to provide limited funding for this project, allowing for the installation of a weir in the lower creek, increased agency assistance during fish spawning, and increased monitoring and evaluation of the supplementation program.

c) Hamma Hamma River Supplementation Project
Hood Canal Salmon Enhancement Group, Long Live the Kings, Point No Point Treaty Council, Skokomish Tribe, U.S. Fish and Wildlife Service, WDFW

The Hamma Hamma multispecies salmonid recovery project was developed by the HCSEG and LLTK with support from others. Out of this effort evolved the Hamma Hamma supplementation project on John Creek, a Hamma Hamma River tributary. Review of freshwater habitat conditions, summer chum escapements, potential causes for decline in escapement, and current restoration efforts in Hood Canal by the tribes, WDFW, USFWS, LLTK, and the HCSEG led to the recommendation for a summer chum supplementation program at John Creek due to the following (Hamma Hamma Supplementation Subcommittee 1997):

- The returns to the Hamma Hamma River comprised an estimated 20 to 30% of the summer chum returns to the west Hood Canal streams in the 1960s and 1970s, but compromise less than 6% of the total run in the past two years.

- Recent returns to the Hamma Hamma River (566-840), unlike the total number of returns to Hood Canal, are not within the range of returns seen in the 1960s and 1970s (1,772-12,800).

- The slower improvement in summer chum salmon returns to the Hamma Hamma River than in the nearby, but non-supplemented, Dosewallips and Duckabush rivers.

- Recent improvement in returns to the Hamma Hamma River does not ensure a future improvement, therefore providing a boost to the population through supplementation may be beneficial if risks are minimized.

- A summer chum salmon supplementation program appears to have been successful at the Quilcene National Fish Hatchery on the Big Quilcene River. This program has been in existence since 1992 and returns to this system have increased dramatically since 1994.

- A supplementation program would require very low levels of human intervention for up to 12 years, and therefore domestication is not foreseen as a problem.

The goal of the Hamma Hamma project is to contribute to the restoration of a healthy, naturally self-sustaining population of Hamma Hamma River summer chum salmon which maintains the genetic characteristics of the native stock. The stated project objective is to lessen the current risk of extinction due to small population size by implementing an effective short-term recovery effort. The summer chum supplementation project is managed through a partnership between LLTK, HCSEG, and WDFW. The project is staffed by LLTK and supported by HCSEG volunteers.

Recovery planning for this watershed was to be consistent with the draft version of the Summer Chum Salmon Conservation Initiative. The contribution of the Hamma Hamma project and its potential expansion will be determined through this comprehensive planning process. Due to lack of experience in working with summer chum salmon in the Hamma Hamma River, it was determined that a small supplementation program was warranted for 1997. This limitation allowed for extra protection for testing of new procedures at a new site.

Through joint agreement between the cooperators, the following guidelines were applied for the operation of the project: 1) the program would attempt to rebuild the run from the existing low level while preserving its genetic character; 2) the program would continue for a maximum of three generations (12 years); 3) all brood stock would be captured in the Hamma Hamma River or its tributary, John Creek; 4) at least 50% of the adults returning to the river in any given year will be allowed to spawn naturally; 5) egg take would be represented over the entire spawning period, and spawning one female to one male should take place; 6) brood stock would be sampled for GSI, scales, and other biological characters, 7) 34 pairs were recommended for broodstock in 1997 to ensure a minimum effective population size of 200 fish in the program (i.e. for a minimum N_e of 200 fish, and an assumed chum generational length of 3 years, 67 chum (34 pairs) are needed) ; 8) in order to prevent the spread of viral pathogens, sampling of all broodstocks will follow appropriate actions mandated by the Co-managers' Disease Policy, and accepted fish health practices and monitoring will be applied during rearing; 9) all fry released would be otolith marked; 10) resulting hatchery fry would be released as 1 gram fish into John Creek or until naturally spawned fry are seen

moving out of the system; 11) the project will include a monitoring and evaluation program; and 12) genetic considerations would be addressed prior to any reintroductions.

During 1997, there were difficulties collecting adequate numbers of brood stock due to flow conditions and the presence of pink salmon in the same areas as summer chum. A total of 5 female and 9 male summer chum were collected and spawned (T. Johnson, WDFW, pers. comm., September, 1998). An estimated 12,000 brood 1997 fry were subsequently released into John Creek on March 1, 1998 at an average size of 1.0 gram. In 1998, WDFW was able to supply a limited amount of funding for this project, allowing for increased agency assistance during fish spawning and increased monitoring and evaluation of the program.

d) Big Beef Creek Summer Chum Reintroduction Project

This reintroduction project is operated jointly by WDFW and USFWS as a cooperative with the Hood Canal Salmon Enhancement Group. Big Beef Creek was initially identified at the onset of long term conservation planning for Hood Canal summer chum as an initial candidate for summer chum reintroduction from the QNFH program. This eastside Hood Canal drainage showed no escapement for ten consecutive years and it was apparent that the indigenous population was extirpated. Big Beef Creek was identified as a suitable location for reintroduction of summer chum from the QNFH program for the following reasons:

- It has historically produced summer chum, and therefore is likely to still possess habitat characteristics that support self-sustaining natural production of summer chum;

- The proposed donor stock is indigenous to a drainage geographically much closer to Big Beef Creek (22.05 km between stream mouths) than the only eastside Hood Canal donor population from which donor summer chum brood stock might be available at the present time (Union River, approx. 69 km distance). No summer chum are available from any other eastern Hood Canal streams for introduction into Big Beef Creek due to extremely low population abundances.

- The spawning ground entry timing for the extirpated Big Beef Creek stock was nearly the same as the entry time identified for the Big Quilcene River population;

- The existing WDFW coho research project on Big Beef Creek provides the necessary infrastructure to conduct assessments of the effects/success of summer chum reintroduction, including adult return levels, smolt out-migrant levels/timing, etc;

- Salmon incubation and production facilities present at the current NMFS/UW program on Big Beef Creek provide opportunities for on-site incubation, hatching and feeding, ensuring imprinting of released fish and increasing survival potential;

- It is desirable from a genetic conservation perspective to establish the Big Quilcene River summer chum genome in another drainage to limit the risk of loss of the population due to catastrophic events. Over the last few years there have been two major flood events on the Quilcene. In the areas of chum spawning, these floods have been especially devastating as a result of gravel scouring, gravel deposition and altering the course of the lower river);

- The Big Beef summer chum run is recognized by all parties as extirpated, and the introduction of a suitable Hood Canal summer chum population from another drainage will therefore not displace or affect an indigenous population.

The following procedures and methods were used in introducing summer chum from the Big Quilcene River into Big Beef Creek during the 1996 and 1997 seasons:

- Eyed eggs identified as surplus to those needed to meet the QNFH on-station fed fry production objective will be transferred to BBC for incubation and hatching in existing NMFS/UW facilities.

- Personnel needs for monitoring incubators and rearing fry will be met by WDFW, USFWS, and the Hood Canal Salmon Enhancement Group.

- Existing facilities at Big Beef Creek will be used for incubating, hatching and rearing of 120,000 to 200,000 summer chum fry for release.

- Procedures used to transfer eyed eggs will comply with the Co-managers' Fish Disease Policy.

- Eyed eggs transferred to BBC will be from egg takes spread across the breadth of the Big Quilcene return to ensure that the entire summer chum return timing span from the donor stock is represented.

- Fry resulting from these transfers will be reared to a target size of 1 gram for an en masse release into Big Beef Creek in March.

In 1997, 204,000 brood 1996 summer chum fry produced in RSIs at Big Beef Creek were released between early February and early March after one to four weeks of rearing in a net-pen positioned in a pond downstream of the NMFS hatchery. The approximate average size at release for 1996 brood chum ranged from 700-1000 fpp. In 1998, approximately 112,000 brood 1997 fed fry at a size of 0.91 grams were released on February 9, after three to four weeks of rearing in a 24 foot diameter fiberglass tank located in the NMFS rearing compound. Approximately 210,000 1998 brood one gram summer chum fry will be released during March, 1999 to complete the third year of the reintroduction program.

2. Strait of Juan de Fuca Region

a) Salmon Creek Summer Chum Supplementation Program WDFW, North Olympic Salmon Coalition, and Wild Olympic Salmon Cooperative

The Salmon Creek supplementation project is a cooperative effort between the North Olympic Salmon coalition, Wild Olympic Salmon and WDFW that was begun in 1992. The project goal is to contribute to the restoration of a healthy, natural, self-sustaining population of Salmon Creek summer chum that will maintain the genetic characteristic of the native stock. An additional goal of the Salmon Creek program, after attaining stable healthy return levels, is to create a donor stock for the reintroduction of summer chum into Chimacum Creek.

The supplementation program, its goal and guidelines, are identified in a 1995 rearing protocol document (WDFW 1995): 1) recovery planning shall be consistent with other WDFW summer chum recovery plans; 2) recovery actions must fully address impacts to other salmonid stocks and not adversely affect their population status; 3) recovery strategies should put the summer chum stock at no greater risk than if no action was taken; 4) the hatchery program will be part of a long-term recovery effort which will have both stock rehabilitation and habitat restoration components; 5) the supplementation program is intended to support natural production, and the program will be discontinued once natural production has been stabilized at healthy stock levels as defined in 1992 SASSI (WDF et al. 1993); 6) the program is limited to twelve years (three chum generations, commencing in 1992), in compliance with stock genetic integrity objectives; 7) at least 50 % of adults returning to Salmon Creek in any given year must spawn naturally; and 8) for 1995, the brood number is initially limited to 10 % of the total number of chum returning to the watershed, with collections occurring over the entire run-timing of the stock.

Following the successful implementation of all protocols required in 1995, the allowable broodstock collection number was adjusted upward to 20 % of the total number of female summer chum returning to the watershed beginning in 1996. In 1995, there were several modifications made to the facility and to the rearing and release process to minimize mortality of eggs and to reduce potential straying. The current program requires that all eggs be transferred to the Dungeness Hatchery for incubation through the eyed stage of development. The eyed eggs are then returned to the Salmon Creek facility for hatching. After emergence, fish are fed in freshwater for two weeks prior to transfer to saltwater net pens in Discovery Bay. The release will be made when the fish are approximately 300 fish/pound. Appendix Table 3.2.3 summarizes releases of summer chum fry since 1992 through the Salmon Creek program.

Appendix Table 3.2.3. Salmon Creek Summer Chum Supplementation program data - 1992-97[1]

Brood Year	Broodstock Removals/Swim-ins			Natural Spawners	Percent Removed	# Fed Fry Released	Release Size (gms)	Release Date
	# Males	# Females	Total					
1992	35	27	62	371	14.3	19,200	1.1	5/08/93
1993	29	23	52	400	11.5	44,000	1.8	4/24/94
1994	12	12	24	137	14.9	2,000	1.3	4/01/95
1995	35	18	53	538	9.0	38,808	1.3	4/24/96
1996	59	50	109	785	12.2	62,000[2]	1.3	4/8,24/97
1997	60	50	110	724	13.2	71,821[2]	1.0-1.3	3/31,4/16/98

[1] Release number and size data from Seymour 1993; Scalf 1995, 1996, 1997; G. Correa, WDFW, Port Townsend, WA pers. comm.

[2] Release numbers do not include 28,788 and 36,840 fry of Salmon Creek-origin released into Chimacum Creek in 1997 and 1998 respectively.

b) Chimacum Creek Summer Chum Reintroduction Project

The previously described Salmon Creek program was originally conceived with the objectives to rebuild and stabilize the Salmon Creek population and to allow for the transfer of surplus eggs or fry to Chimacum Creek. Chimacum Creek was reported to historically have an indigenous summer chum return, but the run was apparently extirpated due mainly to freshwater habitat degradation and poaching. Chimacum Creek was identified as a suitable location for reintroduction of summer chum from Salmon Creek for the following reasons:

- Chimacum Creek historically produced summer chum, and may possess habitat characteristics that have a potential to support self-sustaining natural production;

- Volunteer groups have been working to remedy habitat damage in the Chimacum drainage limiting to salmon production, including silt removal and stream bank stabilization;

- The Salmon Creek summer chum stock is viewed as the appropriate stock for transfer to Chimacum, as the Salmon Creek population is the closest summer chum stock in the region, the two streams are close geographically (stream mouths approximately 34 km apart by water), the watersheds are adjacent to each other, and the stream characteristics are similar;

- It is desirable from a genetic conservation perspective to establish the Salmon Creek summer chum genome in another drainage to limit the risk of loss of the population due to catastrophic events. Salmon Creek is a small watershed and vulnerable to changes that could alter natural chum production; and

- The Chimacum summer chum run is extirpated, and the introduction of a suitable eastern Strait of Juan de Fuca summer chum population from another drainage will therefore not displace or affect an indigenous population.

Given these foundations for summer chum reintroduction, the following procedures and methods in introducing summer chum from Salmon Creek into Chimacum Creek during the 1996-97 and 1997-98 seasons were employed:

- Available surplus eyed eggs from Salmon Creek were transferred to Chimacum Creek for incubation and hatching in RSIs at appropriate locations;

- Facilities on Chimacum Creek will be used for incubating, hatching, and rearing in freshwater. Additional rearing may occur in seawater net-pens in Port Townsend Bay, if an adequate net-pen site is made available.

- Personnel needs for monitoring incubators and rearing fry will be met by volunteers from the North Olympic Salmon Coalition and Wild Olympic Salmon, and by WDFW staff.

- Transfers were done in accordance with established notification process, including notation in the Equilibrium Brood Document.

- Procedures used to transfer eyed eggs complied with the Co-manager's Fish Health Policy.

- Eyed eggs transferred to Chimacum Creek will be from egg takes spread across the breadth of the Salmon Creek return to ensure that the entire summer chum return timing span from the donor stock is represented.

- Fry resulting from this transfer will be reared to a size of 400 fpp for release into lower Chimacum Creek (or from net-pens into Port Townsend Bay) during April.

- Additional transfers in the future will be determined by PNPTC and WDFW.

In 1997, 50,000 eyed eggs were transferred in for the Chimacum program. An estimated 28,788 1996 brood summer chum fry were produced from the egg transfer at the Chimacum High School fish hatchery. These fish were released on March 23 and May 9 at a size ranging from 0.4 to 1.5 grams each from a marine net-pen near the mouth of Chimacum Creek after one to five weeks of additional rearing. In 1998, the transfer of 40,000 eyed eggs from the Salmon Creek program led to the production of 36,840 1997 brood fed fry at an approximate size of 0.7 grams. These fry were transferred in three groups from a rearing site on Naylors Creek, a Chimacum Creek tributary, and released on March 27, April 11, and April 19 into lower Chimacum Creek above the estuary. Initial returns of three year old summer chum from brood year 1996 and 1997 Chimacum Creek releases are anticipated in late summer, 1999 and 2000.

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Appendix Report 3.3
Genetic Hazards Discussion

(This section generally taken from M. Ford, NMFS and K. Currens, NWIFC, "Puget Sound Comprehensive Chinook (Draft) Artificial Production Plan", September, 1998)

Hazard: Reduction in Effective Population Size

General Discussion

Background information on effective population size: The effective size of a population (Ne) is a key parameter in determining both the amount of variation that can be maintained in the population and the relative importance of genetic drift and natural selection in shaping that variation (Hartl and Clark 1989, Lynch and Walsh 1998, Falconer 1989). A population with a small effective size will lose adaptive variation and gain maladaptive variation at a faster rate than an equivalent population with a larger effective size (Lande and Barrowclough 1987, Lande 1994, 1995). The effective size of a population is also directly related to the level of inbreeding that is occurring in the population; small populations have higher levels of inbreeding than larger populations, and therefore may be more vulnerable to inbreeding depression than are larger populations.

The effective size of a population is defined as the size of an idealized population that produces the same level of inbreeding or genetic drift that is seen in an observed population in which one is interested (see Hartl and Clark 1989 and Caballero 1994 for reviews). Attributes of such an idealized population typically include discrete generations, equal sex ratios, binomial variance of reproductive success, random mating, constant breeding population size, and non-selective gamete-to-adult mortality. Violation of any these attributes usually results in an increase in the rate of inbreeding or drift compared to the idealized case, and therefore a reduction in effective population size. For example, if the number of breeding individuals varies from generation to generation, the long term effective size will be equal to the harmonic mean (defined in plan glossary) of the number of breeders each generation (Caballero 1994). Because almost no natural populations are ideal, a population's effective size is almost always smaller than the observed number of breeding individuals (reviewed by Frankam 1995).

Minimum viable effective populations sizes: There are a number of recommendations in the conservation literature on guidelines for "generic" minimum viable effective populations sizes. All of these recommendations are based on effective population size per generation, and for a number of reasons must only be considered as rough guidelines. Franklin (1980) and Soule (1980) suggested that an effective population size of 500 is necessary for long term population persistence. This value is based on estimates of the rates at which mutations add and drift and selection remove variation

from an isolated population. Recently Lande (1995) has pointed out that because ~90% of new mutations are strongly deleterious, a more realistic long term minimum viable effective population size may be closer to 5000 per generation. Based on the probability of losing rare alleles, Waples (1990) has suggested that 100 effective breeders/year is necessary to maintain genetic variation in salmon populations. These general recommendations have some severe limitations that must be acknowledged before they are used to help determine levels of abundance necessary for properly functioning salmon populations. First, they are based on models of single, reproductively isolated populations. As the term is used in this paper, a population is substantially reproductively isolated, but may receive regular migrants from other populations. Migration, like mutation, is a source of genetic variation, so it is likely that populations connected by migration will have somewhat lower genetically minimum viable population sizes than completely isolated populations. Second, the genetic parameters that form the basis for the Franklin (1980) and Lande (1995) recommendations were estimated from limited data, and must therefore be regarded as preliminary. Third, there is some debate about the generality of the genetic model used to obtain these recommendations (e.g. Barton and Turelli 1991). None-the-less, these recommendations may be a reasonable as starting points for determining the abundance necessary for long-term genetic viability, especially in the absence of additional information. Note that other factors, such as habitat capacity and population productivity need to be taken into account when determining appropriate levels of abundance necessary for a population to be considered healthy.

In order to convert these recommendations of effective population size per generation to salmon spawning abundance per year, it is necessary to know the ratio of the effective population size to the census size (Ne/N ratio) and the generation time for the population in question. Ne/N ratios estimated from six populations of Snake River spring chinook and one population of Sacramento River winter chinook range from a low of 0.013 (Bartley et al. 1992) to a high of 0.7 (Waples et al. 1993) and average ~0.4. The large range is most likely due both to large sampling errors in estimating Ne as well as real biological differences among populations. Assuming that an Ne/N ratio of 0.4 is approximately correct for salmon and steelhead in general, the recommended minimum long-term genetically viable population sizes discussed above range from 925/generation (Waples 1990, assuming a 3.6 year generation time) to 12,500/generation (Lande 1995). The minimum spawning population size recommended by WDFW (1997) falls in the middle of this range (3,000/generation). For populations that spawn at multiple age classes, the values of spawners/generation must be divided by the generation length (median age of reproduction) to obtain the corresponding numbers of spawners per year. For Hood Canal summer chum populations, this is estimated to be 3.6 years.

Mechanisms by which artificial propagation can affect Ne: Hatchery management actions can affect Ne in a number of ways. If one considers a hatchery population in isolation, factors under at least some management control such as the broodstock size each year, the variance in productivity among individuals, and the sex ratio all strongly affect Ne. For a given abundance, Ne will be maximized when the sex ratio is equal and the variance in productivity among individuals is minimized. This leads to recommendations such as the use of single pair or factorial mating to maximize Ne (e.g. Tave 1993 Chapter 6, Kapuscinski and Jacobsen 1987). Rearing methods that equalize family size as much as possible can also be used to increase Ne. For example, any culling or transfers to other locations that are done unequally across families will reduce Ne.

The potential effects of artificial propagation on the effective population size of a composite natural/hatchery system are more complicated, and gaining a better understanding of these effects is an active area of research (Ryman and Laikre 1991, Waples and Do 1994, Cuenco 1994). The long term effects of hatchery supplementation on the effective size of the combined wild/hatchery population depend a great deal on factors such as the relative productivities of the two environments, the number of breeders in each environment, whether or not the natural population remains large after supplementation ceases, the age structure of the species, the number of brood years for which broodstock are collected, whether or not returning hatchery fish are avoided for broodstock in the second generation of supplementation, and the environmental and genetic effects on the productivity of hatchery fish that spawn in the wild (Waples and Do 1994, Cuenco 1994). Because of the complicated and contingent nature of these effects, some form of mathematical modeling may be useful to estimate the effects on total effective population size that a particular hatchery program is expected to produce. In the absence of modeling, it is important to keep in mind several key factors explored in other modeling efforts (Ryman and Laikre 1991, Waples and Do 1994, Cuenco 1994) that will influence the likelihood of an increase or decrease in effective population size. These are: 1) Situations where a small number of wild fish are taken into a hatchery and produce a large fraction of natural spawners the following generation can lead to a substantial short term reduction in effective size and increase in inbreeding; 2) If the supplemented population returns to its pre-supplementation size after supplementation ceases, then a decrease in effective size compared to the non-supplemented case is possible, especially if the effective size in the hatchery was small. This suggests that a key component of a supplementation program should be to concurrently address the primary causes that depressed the population in the first place; and 3) If the supplementation program lasts for more than a one generation, marking ~100% of the hatchery fish and avoiding marked fish for use as broodstock can increase effective size. The reader is referred to Ryman and Laikre (1991), Waples and Do (1994) and Cuenco (1994) for a fuller discussion of these issues.

Severity of a Reduction in Ne That Is Considered to Be a Hazard

A reduction in Ne due to artificial propagation is considered to be a hazard if 1) it substantially reduces a wild population's Ne; or 2) reduces a wild population's Ne below 3000 effective spawners/generation; or 3) for target populations below 3000/generation, is expected to result in a lower long-term wild population Ne than would be the case in the absence of the artificial propagation program.

Rationale for Specific Criteria Used in the Risk Assessment (See Worksheets for Assessment of Hazards - Appendix Report 3.4)

Criteria	Rationale
Hatchery fish are marked to accurately estimate the proportion hatchery fish spawning naturally in the target population and the proportion of wild fish spawning in the hatchery	Estimating the proportion of hatchery fish on the spawning grounds and wild fish in the hatchery is essential for an accurate estimation of the effective size of the composite population.
Natural spawners are regularly monitored to accurately estimate the proportion of hatchery fish spawning in the target population.	Same as above.
In the target population, the proportion of natural spawners that are hatchery fish is approximately equal to the proportion of wild fish that were taken into the hatchery the previous generation **OR** In the target population, the proportion of natural spawners that are hatchery fish is larger than the proportion of wild fish that were taken into the hatchery the previous generation **AND** the wild population is increasing in abundance at a rate at least equal to the proportion of naturally spawning hatchery fish **OR** The target wild population is believed to be in substantial danger of extinction within the next 36 years **AND** the effective number of breeders in the hatchery is as large as possible given the available broodstock. **OR** The project is to reintroduce fish to a location removed from the target population with the likelihood of less than 5-15 % return to population.	Meeting this criteria ensures that a small number of hatchery fish cannot contribute a large proportion of natural spawners the next generation and thus substantially reduce Ne. In a supplementation program designed to increase natural abundance, the proportion of natural spawners needs to be larger than the proportion of wild fish taken into the hatchery if the program is to be successful (assuming that the target population is the only source of broodstock). Assuming that the hatchery fish are successful in the natural environment and that the natural population is at least productive enough to be self-sustaining, the supplemented population should increase in abundance at a rate approximately equal to the proportion of the natural spawners that are hatchery fish. If a natural population is not able to sustain itself and is going extinct, then maintaining the population artificially will result in an increase in Ne compared to the case of extinction regardless of the effective population size in the hatchery. In this situation it is important, however, to maintain as much variation as possible to maximize the probability that population may be naturally viable in the future. In the case of reintroduction, the concern is potential project-origin returns to the donor population. A small return if any should not affect the donor population's effective population size.

Hazard: Loss of Within Population Diversity

General Discussion

In principal, six basic parameters are likely to control the degree to which a hatchery program might reduce within population diversity; that is, domesticate a wild population. These are 1) the source of the hatchery broodstock, 2) the degree to which the broodstock sample is representative of the target population (if the target population is itself the broodstock source), 3) the degree of difference between the wild and hatchery environments, 4) the duration of the hatchery program, 5) the level of gene flow between the hatchery and wild environments, and 6) the genetic basis of the traits subject to domestication selection pressure. These factors are discussed in more detail below.

Broodstock source: For the purposes of minimizing the risk of domestication, the best source of broodstock is likely to be the target natural population itself or another, similar, wild population. Hatchery populations that have been in culture for many generations or have ever been deliberately or inadvertently selected for particular traits (e.g. run or spawn timing, age structure, size, etc) are likely to be already at least somewhat domesticated (Reisenbichler 1997). Hatchery populations that have been in culture for some time but have used natural rearing and mating methods and/or had frequent infusions of wild fish into the broodstock may fall somewhere in the middle (Maynard et al. 1995). In at least some instances, evidence for domestication has appeared within two-to-four generations of hatchery rearing (Fleming and Gross 1994, Reisenbichler and McIntyre 1977).

Broodstock collection: A second potential source of domestication is non-representative sampling of wild fish for broodstock. Most natural populations exhibit considerable variation in morphological, behavioral and life-history traits. If fish with certain characteristics are more likely to be sampled for broodstock than their frequency within the population, this may result in selection for those characters in the hatchery population. If the hatchery population is itself reproductively integrated with a wild population, then the distribution of the selected trait may also change in the wild population. In many instances collecting a representative broodstock sample is not likely to be easy. A large random sample will approximate the distribution from which it was drawn, but obtaining a truly random broodstock sample may often be difficult because rarely are all fish in the population available for sampling at the same time. This means that in most cases a sample will have to be stratified over the course of the run in order to obtain a representative sample of the entire population.

Hatchery environment and duration of the hatchery program: The environment that a fish faces in a most hatcheries is different from the wild environment, and morphologies, behaviors and life-history strategies favorable in a hatchery may not be the same as those favorable in the wild. There is evidence to show that many hatchery populations have changed over time at a number of behavioral or morphological traits, and that this divergence can occur over a relatively short time period (e.g. Fleming and Gross 1989, 1992, 1993, 1994, Fleming et al. 1996, McGinnity et al. 1997, Reisenbichler 1997, Berejikian et al. 1997, Swain and Riddell 1990, Berejikian 1995). These changes indicate that the possibility that selection pressures different from those in the wild exist in many hatcheries. In addition, mildly deleterious mutations arise continually in all populations (Kondroshov and Houle 1995) and these may accumulate to higher levels in the relatively protected hatchery environment than they do in the wild (Schultz and Lynch 1997). Hatchery environments that closely resemble wild environments are expected to be less likely to produce substantial domestication pressure than those that are very different from wild environments (Maynard et al.

1995). Likewise, all else being equal, programs of short duration are less likely to cause substantial domestication than programs of long duration.

Gene flow between hatchery and wild environments: The basic concept of populations connected by gene flow that face different selection regimens has been modeled for both the case of traits controlled by a single locus (e.g. Levene 1953, Karlin and McGregor 1972) as well as traits controlled by many loci (e.g. Barton 1983, Phillips 1996, Lythgoe 1997). The results of these models suggest that high levels of gene flow between hatchery and natural environments will ensure that a composite population will not become genetically differentiated into two distinct components. This suggests that the continual infusion of wild fish into hatchery broodstocks should at least slow the domestication process. When gene flow occurs in both directions (wild fish into the hatchery and hatchery fish into the wild), however, these models suggest that the potential exists for a composite population to become adapted to the hatchery, rather than remaining adapted to the wild. At this time, it appears impossible to quantitatively predict the outcome of such composite systems. However, it may be reasonable to assume that a composite population will respond to the average' environment that it experiences, weighted by the proportion of the population in each distinct environment. A reasonable course of action to minimize domestication might therefore be to ensure that the majority of a composite population is naturally propagated. This is an area where theoretical and empirical study would be very useful.

Genetic basis of traits: Most traits that may change as a result of hatchery rearing (e.g. age structure, run timing, size, morphology, etc) are quantitative traits that are likely to be influenced by a large number of genes as well as the environment (Hard 1995). In most cases there is little information on the detailed genetic architecture of these traits, but most animal species, including salmonids, appear to contain some heritable variation at many traits (Lynch and Walsh 1998, Tave 1994). For purposes of risk assessment, it therefore seems reasonable to conclude that most traits subject to domestication selection will have at least some heritable variation upon which selection can act.

Diversity within a population may also be reduced by hatchery induced genetic swamping. This is usually caused by fewer broodstock being collected than planned, combined with the successful culture and release of a large number of fry per adult. Thus, a relatively small proportion of the natural population contributes a disproportionately large number of returning spawners. The success of the original small proportion of the population is artificially improved leading to a genetic swamping effect (see Ryman and Laikre, 1991).

Severity of Loss of Within Population Diversity That Is Considered to Be a Hazard

For purposes of this risk assessment, loss of within population diversity is considered to be a hazard if it will compromise the ability of a population to sustain itself naturally.

Rationale of the Criteria Used for Risk Assessment

Source: Broodstock selection

Criteria	Rationale
Broodstock source is not already substantially domesticated	It appears reasonable to assume that the probability of domestication of a composite population is high if the hatchery component is already domesticated. One exception might be the case where the hatchery population is so different from the wild population that the hatchery population has essentially no reproductive success in the wild. In that case, however, an isolated program may be more feasible or appropriate.

Source: Broodstock collection

Criteria	Rationale
Distributions of morphological, behavioral or life-history traits (e.g. run or spawn timing, size, appearance, age structure, etc) are accurately known for target population	In order to determine if the distributions of traits in the hatchery part of the population are similar to those in the wild, it is necessary to have an understanding of the wild distributions.
Multi-trait distribution of broodstock sample closely matches the multi-trait distribution of target population (e.g. similar run and spawn timing, size, appearance, age structure, etc)	Differences between the wild and hatchery components of a population are evidence that the potential exists for selective differences to have arisen between the two populations. If multi-trait distributions are similar, then one may be at least somewhat more confident that domestication is not occurring than if differences are observed. The number of traits examined and the statistical power to detect differences should also be considered in making this determination (Hard 1995), however. This is an area where generating more detailed guidelines would be useful.
Collection is technically and logistically possible (e.g. site is accessible throughout run, weirs will not be blow out, necessary staff are available to carry out collection, funding is available to measure traits, etc)	Collecting a representative sample of a population may sometimes be logistically difficult (e.g. Bugert 1998). The probability of success depends not only on the collection plan but also on the likelihood that it can be successfully carried out.
The effective population size will be maintained by collecting a minimum of 50 pairs except where the total population is less than 100 fish.	This criterion applies in order to minimize reduction of effective population size and prevent extinction.

Source: Mating, rearing and release methods (degree of difference between wild and hatchery environments) and duration of hatchery program

Criteria	Rationale
Mating and rearing methods are similar enough to those observed in the wild to avoid substantial domestication selection pressure (see below for suggested values)	Differences in mating and rearing between the wild and hatchery environments may be a significant source of potential domestication. Minimizing these differences may therefore reduce the probability of substantial domestication.
OR Hatchery program will be of short duration (3 generations)	The genetic aspects of domestication are a form of evolutionary change, and are not expected to occur instantly. Also, populations that are temporarily perturbed are probably more likely to evolve back to their natural state than populations with a long history of artificial selection. The time period of 3 generations appears to be a reasonable starting point, because summer chum would be subject to any hatchery domestication effects for a relatively short part of their life history (that is, incubation and early fry rearing). This is an area where additional research would be useful.
OR The proportion of natural spawners that are hatchery fish in the target population is less than 5-15%.	As was argued above, it seems likely that a composite population responds evolutionarily to the average' environment that it experiences. It seems likely, therefore, that if only a small portion of the composite population is in an artificial environment substantial domestication will not occur. This is another area where additional research and modeling would be useful.
Hatchery progeny will be released at essentially the same sizes and life-history stages as observed in the target population at the time of release	Same as the rationale for mating and release methods that are similar to wild environment.
OR Hatchery program will be of short duration (3 generations)	Same as above.
OR The proportion of natural spawners that are hatchery fish in the target population is less than 5-15%.	Same as above.

Source: Genetic Swamping (Ryman-Laikre effect)

Criteria	Rationale
Hatchery induced genetic swamping by a small proportion of the population will be avoided.	The swamping effect is likely to begin with fewer broodstock being collected than planned. Consequently, the supplementation program improves survival of a small proportion of the natural population and, as a result, the genetic contribution of the small fraction of the population is increased. The potential for shortfalls in broodstock collection should be addressed in program planning.

Hazard: Loss of among Population Diversity

Endpoints: Target and non-target populations of target species, populations of other species (hatchery structures source)

General Discussion

Evidence for local adaptation: Life history and morphological data (e.g. run timing, size, weight, fecundity, age structure) have been collected from a large number of salmon and steelhead populations (reviewed by Groot and Margolis 1991, Ricker 1972, Taylor 1991, Weitkamp et al. 1995, Busby et al. 1996, Johnson et al. 1997, Gustavson et al. 1997, and Myers et al. 1998), and show that salmon populations vary with respect to these traits. Although the genetic basis of phenotypic variation within and among natural salmon populations has rarely been directly determined, most morphological and life history traits in salmon exhibit genetic variation in captive populations (reviewed by Tave 1992), suggesting that much of the variation among natural salmon populations probably is locally adaptive and due to genetic differences (Ricker 1972 and Taylor 1991). Mark recapture data (e.g. Quinn and Fresh 1984, Quinn et al 1991, Labelle 1992) indicate that straying among salmon populations tends to be variable but generally low, and molecular genetic data (e.g. Parkinson 1984, Gharret et al 1987, Reisenbichler and Phelps 1989, Utter et al 1989, Bartley and Gall 1990, Wood et al 1994, Ford 1998) indicate that genetic differences exist among salmon populations and that many populations are sufficiently reproductively isolated for local adaptations to have evolved (reviewed by Grant 1997). In general it appears that natural salmon populations exist in a dynamic equilibrium between local selection and genetic drift which both promote genetic divergence among populations and straying which promotes genetic homogenization among populations.

Threats to local adaptation: Variation among populations may contribute to the potential for future evolution of the species, and local adaptations among populations probably increase species fitness by allowing populations to become specialized to their local environments. The greatest anthropogenic threats to local adaptation are probably the rapid alteration of the environment to which a local population is adapted, and the introduction of fish of non-local origin that interbreed with local fish. Habitat alteration is discussed in Part Three of the plan, and the remainder of this section deals with the potential effects of non-local introductions and how these might be hazardous to local wild populations. Assuming that a population is indeed locally adapted to its particular environment, this implies that fish from other, non-local, populations carry genotypes that are, on average, less fit in the local environment than those of the local fish. If the rate of migration into a locally adapted population is below some threshold (discussed below), then the non-local genotypes which are deleterious in the local environment will be selected against and the population will come to an equilibrium where deleterious genotypes are removed from the population by selection at the same rate as they enter the population by migration (Barton 1983, Felsenstein 1997). On the other hand, if the rate of migration is greater than some threshold, the rate of selection against deleterious genotypes will be lower than the rate of introduction, and the local adaptations contained by the original population will be lost. The threshold level of migration separating the two scenarios depends on the strength and genetic architecture of local adaptation (i.e. the number of genes involved in local adaptation and how they interact with one another) and the level of interbreeding

between local and non-local fish. Strong selection against migrants, local adaptations that involve small numbers of genes, low rates of recombination among genes and strong assortative mating between local and non-local fish all will lead to relatively high threshold migration levels. Weak selection involving many genes, high levels of recombination and random mating among local and non-local fish will lead to relatively lower threshold migration levels (Karlin and McGregor 1972, Barton 1983, Lythgoe 1997). The number of genes and the level of recombination among them are not known for typical local adaptations, and cannot safely be assumed to be small. In fact, most traits likely to be involved in local adaptation are quantitative traits that are probably controlled by many genes (Hard 1995), and because salmon have a large number of chromosomes (Sola et al 1981) it is probably reasonable to assume that levels of recombination among genes contributing to quantitative traits will be high. This suggests that in general selection/migration thresholds for locally adapted salmon populations are likely to be low. In this context, low" means that the threshold migration rate will be much less than the total strength of selection against migrants, and may be of the order of the selection coefficients for the individual genes contributing to local adaptation. As these selection coefficients may be very small (e.g. < 1%, Grant 1997), the threshold level of migration may also be very small.

A complete evaluation of the effect of straying of non-native hatchery fish should evaluate both the likelihood of the loss of local adaptation (discussed above) as well as the consequences of this loss. If the level of migration is above the selection/migration equilibrium threshold, the maximum loss of fitness would equal the difference in fitness between the original local fish and the non-native migrants. In some cases this difference could be very large, while in other cases the difference in fitness between the local and non-local fish could be so small that there would be little loss of the population's fitness even if all local fish were replaced by migrants.

Although ultimately the loss of among population diversity is considered to be hazard because of its potential effects on the productivity and sustainability of the populations that make up a species or ESU, from an adaptive management perspective it is far easier to monitor and control the effects of artificial propagation on genetic diversity itself rather than on the effects of its loss (Busack and Currens 1995). This is because the mean fitness of a population and the traits that are correlated with it (such as survival between various life stages) varies substantially from year to year due to a large number of environmental and biological factors. Detecting and measuring long term changes in population fitness is difficult to begin with, and positively determining that any one factor, such as loss of among population diversity due to a specific hatchery program, is responsible for the trend is expected to be extremely difficult under most circumstances. Because of this difficulty, if a program relies on monitoring of the potential effects of loss of diversity (changes in population fitness and sustainability) to determine adaptive management actions, it is extremely unlikely that such effects will be detected and appropriate action taken until long after substantial genetic change has already occurred. Based on this argument, Busack and Currens (1995) advocate treating the loss of diversity itself as a hazard and suggest that adaptive management actions be based on monitoring genetic diversity directly, rather than on the consequences of its loss. This argument does not negate the need for continuing research on the ultimate effects of loss of diversity, the results of which will continue to increase understanding of how genetic diversity is related to sustainability and productivity.

Severity of Loss of among Population Diversity That Is Considered to Be a Hazard

For purposes of this risk assessment, a loss of among population diversity is considered to be a hazard if it has the potential to result in the loss of local adaptation among populations. A reasonable approach to limiting potential losses due to straying by non-local hatchery may be something like the following:

Case I: When non-native strays are from a different ESU or are from the same ESU but exhibit substantial genetic, behavioral, life-history, or morphological differences from local fish, the level of straying should be considerably less than the selection/equilibrium threshold or a reasonable estimate of the natural' level of straying between populations with a similar degree of divergence. Using either criteria, this will generally be a very low level of migration (e.g. < 1% of the receiving population consisting of migrants).

Case II: When non-native strays are from the same ESU, one reasonable approach may be to limit stray rates such that they are similar to natural' stray rates estimated from mark/recapture or genetic data.

The second case is most applicable to Hood Canal summer chum.

Rationale for Criteria Used in Risk Assessment

Source of hazard: Broodstock selection

Criteria	Rationale
All the discrete populations within the watershed containing the target population have been correctly identified	One way in which a loss of diversity can occur is if two or more discrete populations are mixed during broodstock collection. In order to avoid this, it is necessary to have a sufficient understanding of the population structure within a watershed to be able to correctly identify a discrete population for broodstock collection. In some cases, it may be appropriate to group two or more populations or spawning aggregates into larger management units, and this also requires knowledge of the population structure within the watershed.
Selected broodstock source is substantially genetically similar to target population	This is a logical necessity to avoid a loss of among population diversity.
Broodstock used for direct reintroduction is used only for one site.	By limiting donor stocks to no more than one reintroduction project the risk of reducing diversity among the total stocks of the ESU is reduced.

Source: Broodstock collection

Criteria	Rationale
It will be possible to collect at a location and time such that only the target population will be collected	The proposed collection protocol must be such that it is possible to collect only the population (or other appropriate management unit) without collecting fish from other populations or units.

Source: Straying

Criteria	Rationale
Hatchery fish will be reared to release size in the watershed targeted for supplementation or reintroduction.	Fish likely will become more strongly imprinted in the watershed targeted for supplementation or reintroduction.
Hatchery fish will be marked to provide effective estimation of straying.	An effective marking program must be planned and implemented to allow for estimation of straying.
Adjacent spawning populations will be effectively monitored to detect straying.	If natural populations are not monitored, it is not possible to know if they are receiving strays or not.

Hazard: Masking of Status

General Discussion

One hazard of artificial propagation is that if substantial numbers of artificially produced fish stray into natural populations, the health and status of those population can be masked. This can occur if, for instance, the hatchery fish are not marked and counted separately from natural fish. In this case, natural abundance would be overestimated. Even if all hatchery fish are marked and counted separately, however, if first generation hatchery fish make up a substantial proportion of natural spawners, then the status of the natural population can still be obscured. For example, one reasonable criteria for a functional, healthy natural population is that it is capable of sustaining its itself in its natural environment over time. This means that, on average, the number of naturally produced spawners in one generation should equal the number of natural spawners the previous generation. The number of naturally produced spawners in one generation divided by the number of natural spawners the previous generation has been termed the Natural Replacement Rate (NRR, Busby et al. 1996), and its long term geometric mean will be equal to approximately 1.0 for a population that is sustaining itself naturally. If, on the other hand, a substantial proportion of the natural spawners are first generation hatchery fish and the population is not growing at a rate at least equal to the proportion of the spawners that are hatchery fish, then the long term NRR will be less than 1.0, indicating that the population is not sustaining itself naturally. An example of this can been seen with upper-Columbia River steelhead, where the NRR is estimated to be ~0.3 (Brown 1995). This statistic is difficult to interpret however, because a large proportion (65% - 85%) of the natural spawners are hatchery fish. If one assumes that naturally spawning hatchery fish are equally productive as naturally spawning wild fish, then this low natural replacement rate indicates that the natural population is falling far short of replacing itself and the presence of naturally spawning hatchery fish may be slowing its decline or keeping it from going extinct. On the other hand, if the hatchery fish have limited productivity in the wild (which may sometimes be the case; see Reisenbichler 1997), a natural replacement rate of 0.3 combined with 65% naturally spawning hatchery fish would indicate that in fact the natural component of the natural spawners may be

replacing itself. As long as a large proportion of the natural spawners are hatchery fish, determining the degree to which a population is naturally self-sustaining is very difficult.

Severity of Masking That Is Considered to Be a Hazard

For purposes of this risk assessment, masking is considered to be a hazard if it substantially compromises the ability to determine if a population is sustaining itself naturally.

Justification for Criteria Used in Risk Assessment

Criteria	Rationale
A sufficient proportion of hatchery fish are marked to estimate hatchery/wild ratios on the spawning grounds	In order to determine if masking is a problem, it is necessary to distinguish between hatchery and natural fish. Marking does not need to be readily visible, and may based on scale or otolith patterns so long as hatchery and wild fish can be reliably distinguished.
Sufficient wild spawning areas (or other appropriate areas such as across weirs or dams) are surveyed to estimate hatchery/wild ratios accurately	In order to determine if masking is a problem, it is necessary to estimate the proportion of natural spawners that are hatchery fish.
Proportion of hatchery fish on spawning grounds is (or will be) less than 5 - 15% OR Hatchery program will be of short duration (three generations) OR Returning hatchery fish will spawn only in habitat currently without any natural spawners of the same species	Severity of masking is directly related to the proportion of hatchery fish on the spawning grounds. The value of 5 - 15% is arbitrary, but seems reasonable. In some cases other values may also be reasonable. Masking is not a substantial concern for programs of short duration, because natural population status will only be obscured for a short period of time. During the initial time period of a reintroduction program if there are no natural spawners present, there is by definition no hazard of masking.

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Appendix Report 3.4
Worksheets for Assessment of Supplementation Hazards

A set of worksheets is used to help assess the risk of hazards from undertaking a supplementation or reintroduction project. The worksheets include 1) a list of the hazards being evaluated (e.g., loss of within population diversity), 2) the specific sources of each hazard (e.g., broodstock collection), 3) criteria to minimize risk of each hazard (e.g., collecting broodstock in a manner that maintains traits of the target population), 4) a rating of the likelihood that each criterion will be achieved (e.g., H = High, M = Moderate and L = Low), and 5) notes or explanation of the rationale behind each criterion rating. Background information of the hazards is provided in the discussion paper contained in Appendix Report 3.3.

A set of worksheets has been completed for each of the potential supplementation and reintroduction projects that are subject to risk assessment in Part Three of the conservation plan and is included in this appendix. The potential projects are:

Supplementation

Union	Lilliwaup	Hamma Hamma	Duckabush
Dosewallips	Big Quilcene	Salmon	Jimmycomelately
Dungeness			

Reintroduction

Big Beef	Chimacum	Tahuya	Dewatto
Skokomish	Anderson	Finch	

The rating for each criterion of the worksheets generally is determined as follows. A specific criterion is given a high likelihood or probability rating where the project, or the procedure required by the criterion, is well understood and there is certainty that the resources are available to meet the criterion. A moderate likelihood or probability is given where there is less certainty that the resources or knowledge is or will be available. Finally, when there is a high level of uncertainty, a low probability is given.

Union Project

Hazard I: Hatchery Failure

Criteria	Probability	Notes
Hatchery personnel live on-site to allow rapid response to water source or power failures.	M	Site and personnel undetermined.
Low pressure/low water alarms functioning for water supplies serving summer chum incubation and rearing areas.	M	Specific project design not yet determined.
All hatchery personnel responsible for rearing fish trained in standard fish propagation and fish health methods.	H	Expect experienced volunteers and trained WDFW staff support.
Incubation and rearing facilities are sited in areas that are not prone to flooding.	M	Expect to site project with low risk of flooding.

Hazard II: Ecological Effects

Criteria	Probability	Notes
Propagated summer chum are released at a life stage (1 gram fed fry) and time (March-April) that will reduce the risk of predation and competition effects on wild fish.	H	Will be key design element.
Summer chum are reared to release size on ground or surface water within the watershed targeted for supplementation or reintroduction.	H	Water source would be within watershed.
Fish health practices developed by the co-managers are applied in all hatchery activities to minimize the risk of fish disease occurrence, transmittal, and catastrophic loss.	H	Expected WDFW staff support would ensure proper procedures and treatment.

Hazard III: Reduction in Effective Population Size

Criteria	Probability	Notes
Hatchery fish are marked to accurately estimate proportion of hatchery fish spawning naturally in target population and proportion of wild fish spawning in hatchery.	H	Expected to be key element to plan for operations.
Natural spawning is regularly monitored to accurately estimate the proportion of hatchery fish spawning in target population.	M	Expected to be key element to plan for operations.
In the target population, the proportion of natural spawners that are hatchery fish is approximately equal to the proportion of wild fish that were taken into the hatchery the previous generation. **OR** In the target population, the proportion of natural spawners that are hatchery-origin fish is	L	Uncertain. But experience indicates that this factor may be difficult to control.

Hazard III: Reduction in Effective Population Size (cont.)

Criteria	Probability	Notes
larger than the proportion of wild fish that were taken into the hatchery the previous generation **AND** the wild population is increasing in abundance at a rate at least equal to the proportion of naturally spawning hatchery-origin fish **OR** The target wild population is believed to be in substantial danger of extinction within the next 35 years AND the effective number of breeders in the hatchery is as large as possible given the available broodstock. **OR** The project is to reintroduce fish to a location removed from the target population with likelihood of less than 5-15% return to target population.		

Hazard IV: Loss of Within Population Diversity

Source: Broodstock selection		
Criteria	Probability	Notes
Broodstock source is not already substantially domesticated.	H	Broodstock has not previously been propagated.

Source: Broodstock collection		
Distributions of morphological, behavioral or life-history traits (e.g. run or spawn timing, size, appearance, age structure, etc) will be collected for target population.	H	Trained staff will record pertinent biological data.
Multi-trait distribution of broodstock sample closely matches the multi-trait distribution of target population (e.g. similar run and spawn timing, size, appearance, age structure, etc).	M	Broodstock collection parameters unknown but key element will be to obtain close match to target population.
Collection is technically and logistically possible (e.g. site is accessible throughout run, weirs have reasonable chance of continuous operation throughout season, necessary staff are available to carry out collection, funding is available to measure traits, etc).	M	Unknown but will be key element of project.
The effective population size will be maintained by collecting a minimum of 50 pairs except where the total population is less than 100 fish.	M	Criterion will be incorporated in plan.

Source: Mating, rearing and release methods (degree of difference between wild and hatchery environments and duration)		
The minimum standard for matings will be one male per female.	H	One to one or factorial matings will be a project objective.
Mating and rearing methods are similar enough to those observed in the wild to avoid substantial domestication selection pressure **OR** Hatchery program will be of short duration (3 generations equal to 12 years) **OR** The proportion of natural spawners that are hatchery-origin fish in the target population is less than 5-15%.	H	Project will be of short duration - not to exceed 12 years.
Hatchery progeny will be released at essentially the same sizes and life-history stages as observed in the target population at the time of release **OR** Hatchery program will be of short duration (3 generations) **OR** The proportion of natural spawners that are hatchery-origin fish in the target population is less than 5-15%.	H	Hatchery progeny to reared to 1 gram size before release; however, program will be of short duration.

Source: Hatchery-induced genetic swamping (Ryman-Laikre effect)		
Broodstocking does not collect a small fraction of the spawner population and, through use of hatchery operation, generate a subsequent large proportion of the natural spawning population.	M	Broodstocking limitations are unknown but avoiding this effect will be a key element of project.

Hazard V: Loss of Among Population Diversity

Source of hazard: Broodstock selection		
Criteria	Probability	Notes
All the discrete populations within the watershed containing the target population have been correctly identified.	H	Total accessible area within watershed surveyed since 1982.
Selected broodstock source is substantially genetically similar to target population.	H	Broodstock source is target population.
Broodstock used for direct reintroduction is used only for one site.	N.A.	

Source: Broodstock collection		
Criteria	Probability	Notes
It will be possible to collect at a location and time such that only the target population will be collected.	H	Only target population exists in watershed.

Source: Straying		
Criteria	Probability	Notes
Hatchery fish will be reared to release size in the watershed targeted for supplementation or reintroduction.	H	Location of facilities in watershed will be key element of project.
Hatchery fish will be marked to provide effective estimation of straying.	H	Fish will be marked to differentiate hatchery-origin and natural-origin spawners within watershed.
Adjacent spawning populations will be effectively monitored to detect straying.	L	Undetermined at this time.

Hazard VI: Masking of Population Status

Criteria	Probability	Notes
A sufficient proportion of hatchery fish are marked to estimate hatchery/wild ratios on the spawning grounds.	H	Expect to provide for adequate marking.
Sufficient wild spawning areas are surveyed to estimate hatchery/wild ratios accurately.	M	Expect would be key element to plan for operations.
Proportion of hatchery fish on spawning grounds is (or will be) less than 5-15% **OR** Hatchery program will be of short duration (3 generations equal to 12 years) **OR** Returning hatchery fish will spawn primarily in habitat currently underutilized by natural spawners of the same species.	H	Expect returning hatchery-origin fish will spawn in habitat currently under-utilized and project is of short duration.

Lilliwaup Project

Hazard I: Hatchery Failure

Criteria	Probability	Notes
Hatchery personnel live on-site to allow rapid response to water source or power failures.	H	One person lives on-station. Hatchery Manager is on 24 hour stand by.
Low pressure/low water alarms functioning for water supplies serving summer chum incubation and rearing areas.	H	Alarm system is in place.
All hatchery personnel responsible for rearing fish trained in standard fish propagation and fish health methods.	H	Experienced hatchery manager. Trained WDFW staff support.
Incubation and rearing facilities are sited in areas that are not prone to flooding.	H	Facilities are located in areas of low flooding risk.

Hazard II: Ecological Effects

Criteria	Probability	Notes
Propagated summer chum are released at a life stage (1 gram fed fry) and time (March-April) that will reduce the risk of predation and competition effects on wild fish.	H	Capability has been demonstrated at site.
Summer chum are reared to release size on ground or surface water within the watershed targeted for supplementation or reintroduction.	H	Surface water source within watershed.
Fish health practices developed by the co-managers are applied in all hatchery activities to minimize the risk of fish disease occurrence, transmittal, and catastrophic loss.	H	WDFW staff support ensures proper procedures and treatment.

Hazard III: Reduction in Effective Population Size

Criteria	Probability	Notes
Hatchery fish are marked to accurately estimate proportion of hatchery fish spawning naturally in target population and proportion of wild fish spawning in hatchery.	H	Funding, equipment and staff are available to otolith mark all releases.
Natural spawning is regularly monitored to accurately estimate the proportion of hatchery fish spawning in target population.	M	Intent is to sample, read and analyze otoliths of spawning population, but funding and resources have not yet been secured.
In the target population, the proportion of natural spawners that are hatchery fish is approximately equal to the proportion of wild fish that were taken into the hatchery the previous generation **OR** In the target population, the proportion of natural spawners that are hatchery-origin fish is larger than the proportion of wild fish that were taken into the hatchery the previous generation **AND** the wild population is increasing in abundance at a rate at least	H	The target population is at high risk of extinction with average of 61 spawners over past five years (1993-97) compared to five year average of 937 spawners from 1974 through 1978. Broodstock is to be collected consistent with guidelines

Hazard III: Reduction in Effective Population Size (cont.)

equal to the proportion of naturally spawning hatchery-origin fish **OR** **The target wild population is believed to be in substantial danger of extinction within the next 35 years AND the effective number of breeders in the hatchery is as large as possible given the available broodstock.** **OR** The project is to reintroduce fish to a location removed from the target population with likelihood of less than 5-15% return to target population.		(i.e., 50 pairs unless total spawning population is less than 100 fish).

Hazard IV: Loss of Within Population Diversity

Source: Broodstock selection		
Criteria	Probability	Notes
Broodstock source is not already substantially domesticated.	H	Project begun with brood year 1992.

Source: Broodstock collection		
Distributions of morphological, behavioral or life-history traits (e.g. run or spawn timing, size, appearance, age structure, etc) will be collected for target population.	H	Trained staff records pertinent biological data.
Multi-trait distribution of broodstock sample closely matches the multi-trait distribution of target population (e.g. similar run and spawn timing, size, appearance, age structure, etc).	M	Location, timing and protocol of collection intended to achieve matching.
Collection is technically and logistically possible (e.g. site is accessible throughout run, weirs have reasonable chance of continuous operation throughout season, necessary staff are available to carry out collection, funding is available to measure traits, etc).	M	New plan and staff in place were successful in first year.
The effective population size will be maintained by collecting a minimum of 50 pairs except where the total population is less than 100 fish.	M	New plan and staff in place were successful in first year.

Source: Mating, rearing and release methods (degree of difference between wild and hatchery environments and duration)		
The minimum standard for matings will be one male per female.	H	One to one or factorial matings to be used.
Mating and rearing methods are similar enough to those observed in the wild to avoid substantial domestication selection pressure **OR** Hatchery program will be of short duration (3 generations equal to 12 years) **OR** The proportion of natural spawners that are hatchery-origin fish in the target population is less than 5-15%.	H	Project to be of short duration - not to exceed 12 years.

Source: Mating, rearing and release methods (degree of difference between wild and hatchery environments and duration) (cont.)		
Hatchery progeny will be released at essentially the same sizes and life-history stages as observed in the target population at the time of release **OR** Hatchery program will be of short duration (3 generations) **OR** The proportion of natural spawners that are hatchery-origin fish in the target population is less than 5-15%.	H	Hatchery progeny to reared to 1 gram size before release; however, program will be of short duration.

Source: Hatchery-induced genetic swamping (Ryman-Laikre effect)		
Broodstocking does not collect a small fraction of the spawner population and, through use of hatchery operation, generate a subsequent large proportion of the natural spawning population.	M	New broodstocking site and weir being tested.

Hazard V: Loss of Among Population Diversity

Source of hazard: Broodstock selection		
Criteria	Probability	Notes
All the discrete populations within the watershed containing the target population have been correctly identified.	H	Total accessible area within watershed surveyed since mid-70s.
Selected broodstock source is substantially genetically similar to target population.	H	Broodstock source is target population.
Broodstock used for direct reintroduction is used only for one site.	N.A.	

Source: Broodstock collection		
Criteria	Probability	Notes
It will be possible to collect at a location and time such that only the target population will be collected.	H	Only target population exists in watershed.

Source: Straying		
Criteria	Probability	Notes
Hatchery fish will be reared to release size in the watershed targeted for supplementation or reintroduction.	H	Incubation and rearing facilities located in watershed.
Hatchery fish will be marked to provide effective estimation of straying.	H	Staff, equipment and funding exist to otolith mark all releases.
Adjacent spawning populations will be effectively monitored to detect straying.	L	Funding and resources have not been secured for otolith sampling, reading and analysis.

Hazard VI: Masking of Population Status

Criteria	Probability	Notes
A sufficient proportion of hatchery fish are marked to estimate hatchery/wild ratios on the spawning grounds.	H	All releases will be otolith marked.
Sufficient wild spawning areas are surveyed to estimate hatchery/wild ratios accurately.	M	Intent is to sample, read and analyze otoliths of spawning population but funding and resources have not yet been secured.
Proportion of hatchery fish on spawning grounds is (or will be) less than 5-15% **OR** Hatchery program will be of short duration (3 generations equal to 12 years) **OR** Returning hatchery fish will spawn primarily in habitat currently underutilized by natural spawners of the same species.	H	Returning hatchery fish will spawn in habitat currently underutilized by target population and project is of short duration.

Hamma Hamma Project

Hazard I: Hatchery Failure

Criteria	Probability	Notes
Hatchery personnel live on-site to allow rapid response to water source or power failures.	M	Hatchery personnel do not live on-site but no major risk to water supply has been demonstrated.
Low pressure/low water alarms functioning for water supplies serving summer chum incubation and rearing areas.	M	No alarm system presently exists but no major risk.
All hatchery personnel responsible for rearing fish trained in standard fish propagation and fish health methods.	H	Experienced volunteers. Trained WDFW staff support.
Incubation and rearing facilities are sited in areas that are not prone to flooding.	M	Rearing pond may be susceptible at high flows.

Hazard II: Ecological Effects

Criteria	Probability	Notes
Propagated summer chum are released at a life stage (1 gram fed fry) and time (March-April) that will reduce the risk of predation and competition effects on wild fish.	H	Capability has been demonstrated at site.
Summer chum are reared to release size on ground or surface water within the watershed targeted for supplementation or reintroduction.	H	Ground water source within watershed.
Fish health practices developed by the co-managers are applied in all hatchery activities to minimize the risk of fish disease occurrence, transmittal, and catastrophic loss.	H	WDFW staff support ensures proper procedures and treatment.

Hazard III: Reduction in Effective Population Size

Criteria	Probability	Notes
Hatchery fish are marked to accurately estimate proportion of hatchery fish spawning naturally in target population and proportion of wild fish spawning in hatchery.	H	Funding, equipment and staff are available to otolith mark all releases.
Natural spawning are regularly monitored to accurately estimate the proportion of hatchery fish spawning in target population.	M	Intent is to sample, read and analyze otoliths of spawning population, but funding and resources have not yet been secured.
In the target population, the proportion of natural spawners that are hatchery fish is approximately equal to the proportion of wild fish that were taken into the hatchery the previous generation **OR** In the target population, the proportion of natural spawners that are hatchery-origin fish is larger than the proportion of wild fish that were taken into the hatchery the previous generation **AND** the wild population is increasing in abundance at a rate at least	L	Uncertain. But experience indicates that this factor may be difficult to control.

Hazard III: Reduction in Effective Population Size (cont.)

equal to the proportion of naturally spawning hatchery-origin fish **OR** The target wild population is believed to be in substantial danger of extinction within the next 35 years AND the effective number of breeders in the hatchery is as large as possible given the available broodstock. **OR** The project is to reintroduce fish to a location removed from the target population with likelihood of less than 5-15% return to target population.		

Hazard IV: Loss of Within Population Diversity

Source: Broodstock selection		
Criteria	Probability	Notes
Broodstock source is not already substantially domesticated.	H	Project begun with brood year 1997.

Source: Broodstock collection		
Distributions of morphological, behavioral or life-history traits (e.g. run or spawn timing, size, appearance, age structure, etc) will be collected for target population.	L	Effective broodstocking and sampling does not yet exist.
Multi-trait distribution of broodstock sample closely matches the multi-trait distribution of target population (e.g. similar run and spawn timing, size, appearance, age structure, etc).	M	Location, timing and protocol of collection intended to achieve matching.
Collection is technically and logistically possible (e.g. site is accessible throughout run, weirs have reasonable chance of continuous operation throughout season, necessary staff are available to carry out collection, funding is available to measure traits, etc).	L	Effective approach to broodstock collection not yet developed.
The effective population size will be maintained by collecting a minimum of 50 pairs except where the total population is less than 100 fish.	L	Effective collection still lacking.

Source: Mating, rearing and release methods (degree of difference between wild and hatchery environments and duration)		
The minimum standard for matings will be one male per female.	H	One to one or factorial matings will be used.
Mating and rearing methods are similar enough to those observed in the wild to avoid substantial domestication selection pressure **OR** Hatchery program will be of short duration (3 generations equal to 12 years) **OR** The proportion of natural spawners that are hatchery-origin fish in the target population is less than 5-15%.	H	Project to be of short duration - not to exceed 12 years.

Source: Mating, rearing and release methods (degree of difference between wild and hatchery environments and duration)		
Hatchery progeny will be released at essentially the same sizes and life-history stages as observed in the target population at the time of release **OR** Hatchery program will be of short duration (3 generations) **OR** The proportion of natural spawners that are hatchery-origin fish in the target population is less than 5-15%.	H	Hatchery progeny to reared to 1 gram size before release; however, program will be of short duration.

Source: Hatchery-induced genetic swamping (Ryman-Laikre effect)		
Broodstocking does not collect a small fraction of the spawner population and, through use of hatchery operation, generate a subsequent large proportion of the natural spawning population.	M	New broodstock collection plan but untested.

Hazard V: Loss of Among Population Diversity

Source of hazard: Broodstock selection		
Criteria	Probability	Notes
All the discrete populations within the watershed containing the target population have been correctly identified.	H	Total accessible area within watershed surveyed since mid-70s
Selected broodstock source is substantially genetically similar to target population.	H	Broodstock source is target population.
Broodstock used for direct reintroduction is used only for one site.	N.A.	

Source: Broodstock collection		
Criteria	Probability	Notes
It will be possible to collect at a location and time such that only the target population will be collected.	H	Only target population exists in watershed.

Source: Straying		
Criteria	Probability	Notes
Hatchery fish will be reared to release size in the watershed targeted for supplementation or reintroduction.	H	Incubation and rearing facilities located in watershed.
Hatchery fish will be marked to provide effective estimation of straying.	H	Staff, equipment and funding exist to otolith mark all releases.
Adjacent spawning populations will be effectively monitored to detect straying.	L	Funding and resources have not been secured for otolith sampling, reading and analysis.

Hazard VI: Masking of Population Status

Criteria	Probability	Notes
A sufficient proportion of hatchery fish are marked to estimate hatchery/wild ratios on the spawning grounds.	H	All releases will be otolith marked.
Sufficient wild spawning areas are surveyed to estimate hatchery/wild ratios accurately.	M	Funding and resources have not been secured for otolith sampling, reading and analysis.
Proportion of hatchery fish on spawning grounds is (or will be) less than 5-15% **OR** Hatchery program will be of short duration (3 generations equal to 12 years) **OR** Returning hatchery fish will spawn primarily in habitat currently underutilized by natural spawners of the same species.	H	Returning hatchery fish will spawn in habitat currently underutilized by target population and project is of short duration.

Duckabush Project

Hazard I: Hatchery Failure

Criteria	Probability	Notes
Hatchery personnel live on-site to allow rapid response to water source or power failures.	M	Site and personnel undetermined.
Low pressure/low water alarms functioning for water supplies serving summer chum incubation and rearing areas.	M	Specific project design not yet determined.
All hatchery personnel responsible for rearing fish trained in standard fish propagation and fish health methods.	H	Expect experienced volunteers and trained WDFW staff support.
Incubation and rearing facilities are sited in areas that are not prone to flooding.	M	Undetermined but expect to site project with low risk of flooding.

Hazard II: Ecological Effects

Criteria	Probability	Notes
Propagated summer chum are released at a life stage (1 gram fed fry) and time (March-April) that will reduce the risk of predation and competition effects on wild fish.	H	Will be key design element.
Summer chum are reared to release size on ground or surface water within the watershed targeted for supplementation or reintroduction.	H	Water source would be within watershed.
Fish health practices developed by the co-managers are applied in all hatchery activities to minimize the risk of fish disease occurrence, transmittal, and catastrophic loss.	H	Expected WDFW staff support would ensure proper procedures and treatment.

Hazard III: Reduction in Effective Population Size

Criteria	Probability	Notes
Hatchery fish are marked to accurately estimate proportion of hatchery fish spawning naturally in target population and proportion of wild fish spawning in hatchery.	H	Expected to be key element to plan for operations.
Natural spawning is regularly monitored to accurately estimate the proportion of hatchery fish spawning in target population.	M	Expected to be key element to plan for operations.
In the target population, the proportion of natural spawners that are hatchery fish is approximately equal to the proportion of wild fish that were taken into the hatchery the previous generation **OR** In the target population, the proportion of natural spawners that are hatchery-origin fish is larger than the proportion of wild fish that were taken into the hatchery the previous generation **AND** the wild population is increasing in abundance at a rate at least equal to the proportion of naturally spawning hatchery-origin fish	L	Uncertain. But experience indicates that this factor may be difficult to control.

Hazard III: Reduction in Effective Population Size

OR The target wild population is believed to be in substantial danger of extinction within the next 35 years AND the effective number of breeders in the hatchery is as large as possible given the available broodstock. **OR** The project is to reintroduce fish to a location removed from the target population with likelihood of less than 5-15% return to target population.		

Hazard IV: Loss of Within Population Diversity

Source: Broodstock selection		
Criteria	Probability	Notes
Broodstock source is not already substantially domesticated.	H	Broodstock has not previously been propagated.

Source: Broodstock collection		
Distributions of morphological, behavioral or life-history traits (e.g. run or spawn timing, size, appearance, age structure, etc) will be collected for target population.	H	Trained staff will record pertinent biological data.
Multi-trait distribution of broodstock sample closely matches the multi-trait distribution of target population (e.g. similar run and spawn timing, size, appearance, age structure, etc).	M	Broodstock collection parameters unknown but key element will be to obtain close match to target population.
Collection is technically and logistically possible (e.g. site is accessible throughout run, weirs have reasonable chance of continuous operation throughout season, necessary staff are available to carry out collection, funding is available to measure traits, etc).	M	Unknown but will be key element of project.
The effective population size will be maintained by collecting a minimum of 50 pairs except where the total population is less than 100 fish.	M	Criterion will be incorporated in plan.

Source: Mating, rearing and release methods (degree of difference between wild and hatchery environments and duration)		
The minimum standard for matings will be one male per female.	H	One to one or factorial matings will be a project objective.

Mating and rearing methods are similar enough to those observed in the wild to avoid substantial domestication selection pressure **OR** Hatchery program will be of short duration (3 generations equal to 12 years) **OR** The proportion of natural spawners that are hatchery-origin fish in the target population is less than 5-15%.	H	Project will be of short duration - not to exceed 12 years.
Source: Mating, rearing and release methods (degree of difference between wild and hatchery environments and duration) (cont.)		
Hatchery progeny will be released at essentially the same sizes and life-history stages as observed in the target population at the time of release **OR** Hatchery program will be of short duration (3 generations) **OR** The proportion of natural spawners that are hatchery-origin fish in the target population is less than 5-15%.	H	Hatchery progeny to reared to 1 gram size before release; however, program will be of short duration.

Source: Hatchery-Induced Genetic Swamping (Ryman-Laikre effect)		
Broodstocking does not collect a small fraction of the spawner population and, through use of hatchery operation, generate a subsequent large proportion of the natural spawning population.	M	Broodstocking limitations are unknown but project will be operated to avoid this effect.

Hazard V: Loss of Among Population Diversity

Source of hazard: Broodstock selection		
Criteria	Probability	Notes
All the discrete populations within the watershed containing the target population have been correctly identified.	H	Total accessible area within watershed surveyed since 1982.
Selected broodstock source is substantially genetically similar to target population.	H	Broodstock source is target population.
Broodstock used for direct reintroduction is used only for one site.	N.A.	

Source: Broodstock collection		
Criteria	Probability	Notes
It will be possible to collect at a location and time such that only the target population will be collected.	H	Only target population exists in watershed.

Source: Straying		
Criteria	Probability	Notes
Hatchery fish will be reared to release size in the watershed targeted for supplementation or reintroduction.	H	Location of facilities in watershed will be key element of project.
Hatchery fish will be marked to provide effective estimation of straying.	H	Fish will be marked to differentiate hatchery-origin and natural-origin spawners within watershed.
Adjacent spawning populations will be effectively monitored to detect straying.	L	Undetermined at this time.

Hazard VI: Masking of Population Status

Criteria	Probability	Notes
A sufficient proportion of hatchery fish are marked to estimate hatchery/wild ratios on the spawning grounds.	H	Expect to provide for adequate marking.
Sufficient wild spawning areas are surveyed to estimate hatchery/wild ratios accurately.	M	Would be key element to plan for operations.
Proportion of hatchery fish on spawning grounds is (or will be) less than 5-15% **OR** Hatchery program will be of short duration (3 generations equal to 12 years) **OR** Returning hatchery fish will spawn primarily in habitat currently underutilized by natural spawners of the same species.	H	Returning hatchery-origin fish will spawn in habitat currently under-utilized and project is of short duration.

Dosewallips Project

Hazard I: Hatchery Failure

Criteria	Probability	Notes
Hatchery personnel live on-site to allow rapid response to water source or power failures.	M	Site and personnel undetermined.
Low pressure/low water alarms functioning for water supplies serving summer chum incubation and rearing areas.	M	Specific project design not yet determined.
All hatchery personnel responsible for rearing fish trained in standard fish propagation and fish health methods.	H	Expect experienced volunteers and trained WDFW staff support.
Incubation and rearing facilities are sited in areas that are not prone to flooding.	M	Undetermined but expect to site project with low risk of flooding.

Hazard II: Ecological Effects

Criteria	Probability	Notes
Propagated summer chum are released at a life stage (1 gram fed fry) and time (March-April) that will reduce the risk of predation and competition effects on wild fish.	H	Will be key design element..
Summer chum are reared to release size on ground or surface water within the watershed targeted for supplementation or reintroduction.	H	Water source would be within watershed.
Fish health practices developed by the co-managers are applied in all hatchery activities to minimize the risk of fish disease occurrence, transmittal, and catastrophic loss.	H	Expected WDFW staff support would ensure proper procedures and treatment.

Hazard III: Reduction in Effective Population Size

Criteria	Probability	Notes
Hatchery fish are marked to accurately estimate proportion of hatchery fish spawning naturally in target population and proportion of wild fish spawning in hatchery.	H	Expected to be key element to plan for operations.
Natural spawning is regularly monitored to accurately estimate the proportion of hatchery fish spawning in target population.	M	Expected to be key element to plan for operations.
In the target population, the proportion of natural spawners that are hatchery fish is approximately equal to the proportion of wild fish that were taken into the hatchery the previous generation **OR** In the target population, the proportion of natural spawners that are hatchery-origin fish is larger than the proportion of wild fish that were taken into the hatchery the previous generation **AND** the wild population is increasing in abundance at a rate at least equal to the proportion of naturally spawning hatchery-origin fish	L	Uncertain. But experience indicates that this factor may be difficult to control.

Hazard III: Reduction in Effective Population Size (cont.)

OR The target wild population is believed to be in substantial danger of extinction within the next 35 years AND the effective number of breeders in the hatchery is as large as possible given the available broodstock. **OR** The project is to reintroduce fish to a location removed from the target population with likelihood of less than 5-15% return to target population.		

Hazard IV: Loss of Within Population Diversity

Source: Broodstock selection		
Criteria	Probability	Notes
Broodstock source is not already substantially domesticated.	H	Broodstock has not previously been propagated.

Source: Broodstock collection		
Distributions of morphological, behavioral or life-history traits (e.g. run or spawn timing, size, appearance, age structure, etc) will be collected for target population.	H	Trained staff will record pertinent biological data.
Multi-trait distribution of broodstock sample closely matches the multi-trait distribution of target population (e.g. similar run and spawn timing, size, appearance, age structure, etc).	M	Broodstock collection parameters unknown but key element will be to obtain close match to target population.
Collection is technically and logistically possible (e.g. site is accessible throughout run, weirs have reasonable chance of continuous operation throughout season, necessary staff are available to carry out collection, funding is available to measure traits, etc).	M	Unknown but will be key element of project.
The effective population size will be maintained by collecting a minimum of 50 pairs except where the total population is less than 100 fish.	M	Criterion will be incorporated in plan.

Source: Mating, rearing and release methods (degree of difference between wild and hatchery environments and duration)		
The minimum standard for matings will be one male per female.	H	One to one or factorial matings will be a project objective.
Mating and rearing methods are similar enough to those observed in the wild to avoid substantial domestication selection pressure **OR** Hatchery program will be of short duration (3 generations equal to 12 years) **OR** The proportion of natural spawners that are hatchery-origin fish in the target population is less than 5-15%.	H	Project will be of short duration - not to exceed 12 years.

Source: Mating, rearing and release methods (degree of difference between wild and hatchery environments and duration) (cont.)		
Hatchery progeny will be released at essentially the same sizes and life-history stages as observed in the target population at the time of release **OR** Hatchery program will be of short duration (3 generations) **OR** The proportion of natural spawners that are hatchery-origin fish in the target population is less than 5-15%.	H	Hatchery progeny to reared to 1 gram size before release; however, program will be of short duration.

Source: Hatchery-Induced Genetic Swamping (Ryman-Laikre effect)		
Broodstocking does not collect a small fraction of the spawner population and, through use of hatchery operation, generate a subsequent large proportion of the natural spawning population.	M	Broodstocking limitations are unknown but project will be operated to avoid this effect.

Hazard V: Loss of Among Population Diversity

Source of hazard: Broodstock selection		
Criteria	Probability	Notes
All the discrete populations within the watershed containing the target population have been correctly identified.	H	Total accessible area within watershed surveyed since 1982.
Selected broodstock source is substantially genetically similar to target population.	H	Broodstock source is target population.
Broodstock used for direct reintroduction is used only for one site.	N.A.	

Source: Broodstock collection		
Criteria	Probability	Notes
It will be possible to collect at a location and time such that only the target population will be collected.	H	Only target population exists in watershed.

Source: Straying		
Criteria	Probability	Notes
Hatchery fish will be reared to release size in the watershed targeted for supplementation or reintroduction.	H	Location of facilities in watershed will be key element of project.
Hatchery fish will be marked to provide effective estimation of straying.	H	Fish will be marked to differentiate hatchery-origin and natural-origin spawners within watershed.
Adjacent spawning populations will be effectively monitored to detect straying.	L	Undetermined at this time.

Hazard VI: Masking of Population Status

Criteria	Probability	Notes
A sufficient proportion of hatchery fish are marked to estimate hatchery/wild ratios on the spawning grounds.	H	Expect to provide for adequate marking.
Sufficient wild spawning areas are surveyed to estimate hatchery/wild ratios accurately.	M	Would be key element to plan for operations.
Proportion of hatchery fish on spawning grounds is (or will be) less than 5-15% **OR** Hatchery program will be of short duration (3 generations equal to 12 years) **OR** Returning hatchery fish will spawn primarily in habitat currently underutilized by natural spawners of the same species.	H	Returning hatchery-origin fish will spawn in habitat currently under-utilized and project is of short duration.

Big Quilcene Project

Hazard I: Hatchery Failure

Criteria	Probability	Notes
Hatchery personnel live on-site to allow rapid response to water source or power failures.	H	Three occupied residences on-site.
Low pressure/low water alarms functioning for water supplies serving summer chum incubation and rearing areas.	H	Alarm system is in place.
All hatchery personnel responsible for rearing fish trained in standard fish propagation and fish health methods.	H	Trained and experienced USFWS staff work on station or are otherwise available.
Incubation and rearing facilities are sited in areas not prone to flooding.	H	Facilities are in hatchery facility at low risk of flooding.

Hazard II: Ecological Effects

Criteria	Probability	Notes
Propagated summer chum are released at a life stage (1 gram fed fry) and time (March-April) that will reduce the risk of predation and competition effects on wild fish.	H	Capability has been demonstrated at site.
Summer chum are reared to release size on ground or surface water within the watershed targeted for supplementation or reintroduction.	H	Surface water sources within watershed.
Fish health practices developed by the co-managers are applied in all hatchery activities to minimize the risk of fish disease occurrence, transmittal, and catastrophic loss.	H	USFWS pathologists ensure compliance with agreed fish health practices.

Hazard III: Reduction in Effective Population Size

Criteria	Probability	Notes
Hatchery fish are marked to accurately estimate proportion of hatchery fish spawning naturally in target population and proportion of wild fish spawning in hatchery.	H	Staff and equipment exist to mark all releases with adipose fin clip. USFWS will fund marking for duration of program.
Natural spawning is regularly monitored to accurately estimate the proportion of hatchery fish spawning in target population.	H	WDFW index survey stream. USFWS staff also perform surveys.
In the target population, the proportion of natural spawners that are hatchery fish is approximately equal to the proportion of wild fish that were taken into the hatchery the previous generation **OR** In the target population, the proportion of natural spawners that are hatchery-origin fish is larger than the proportion of wild fish that were taken into the hatchery the previous generation **AND** the wild population is increasing in abundance at a rate at least equal to the proportion of naturally spawning hatchery-origin fish	L	There has not yet been an effective estimate of the proportion of hatchery fish in the target population. However, all released fish are now marked beginning with brood year 1997 and future estimates will be available. The high escapements since hatchery-origin returns were first expected (as 3 year olds) suggest that the proportion of natural spawners that are hatchery-origin fish is greater

Hazard III: Reduction in Effective Population Size (cont.)

OR The target wild population is believed to be in substantial danger of extinction within the next 35 years **AND** the effective number of breeders in the hatchery is as large as possible given the available broodstock. **OR** The project is to reintroduce fish to a location removed from the target population with likelihood of less than 5-15% return to target population.		than the proportion of wild fish that were taken into the hatchery the previous generation.

Hazard IV: Loss of Within Population Diversity

Source: Broodstock selection		
Criteria	Probability	Notes
Broodstock source is not already substantially domesticated.	H	Project begun with brood year 1992.

Source: Broodstock collection		
Distributions of morphological, behavioral or life-history traits (e.g. run or spawn timing, size, appearance, age structure, etc) will be collected for target population.	M	Trained staff records pertinent biological data but required collection procedure limits trait assessment.
Multi-trait distribution of broodstock sample closely matches the multi-trait distribution of target population (e.g. similar run and spawn timing, size, appearance, age structure, etc).	M	Collection procedure limits trait assessment.
Collection is technically and logistically possible (e.g. site is accessible throughout run, weirs have reasonable chance of continuous operation throughout season, necessary staff are available to carry out collection, funding is available to measure traits, etc).	H	Demonstrated technical and logistical collection capability
The effective population size will be maintained by collecting a minimum of 50 pairs except where the total population is less than 100 fish.	H	Past experience shows high probability of meeting criterion.

Source: Mating, rearing and release methods (degree of difference between wild and hatchery environments and duration)		
The minimum standard for matings will be one male per female.	H	One to one matings are used.
Mating and rearing methods are similar enough to those observed in the wild to avoid substantial domestication selection pressure **OR** Hatchery program will be of short duration (3 generations equal to 12 years) **OR** The proportion of natural spawners that are hatchery-origin fish in the target population is less than 5-15%.	H	Project to be of short duration - not to exceed 12 years.

Source: Mating, rearing and release methods (degree of difference between wild and hatchery environments and duration)		
Hatchery progeny will be released at essentially the same sizes and life-history stages as observed in the target population at the time of release **OR** Hatchery program will be of short duration (3 generations) **OR** The proportion of natural spawners that are hatchery-origin fish in the target population is less than 5-15%.	H	Hatchery progeny are reared to 1 gram size before release; however, program will be of short duration.

Source: Hatchery-Induced Genetic Swamping (Ryman-Laikre effect)		
Broodstocking does not collect a small fraction of the spawner population and, through use of hatchery operation, generate a subsequent large proportion of the natural spawning population.	H	Past experience shows high probability of meeting criterion.

Hazard V: Loss of Among Population Diversity

Source of hazard: Broodstock selection		
Criteria	Probability	Notes
All the discrete populations within the watershed containing the target population have been correctly identified.	H	Total accessible area of stock surveyed since mid-70s.
Selected broodstock source is substantially genetically similar to target population.	H	Broodstock source is target population.
Broodstock used for direct reintroduction is used only for one site.	H	Only one direct reintroduction site, separate from Quilcene stock is being used; i.e, Big Beef.

Source: Broodstock collection		
Criteria	Probability	Notes
It will be possible to collect at a location and time such that only the target population will be collected.	H	Broodstock collection within the bay most likely to be from target stock (i.e., fish in the two streams of Quilcene Bay are assumed to be same stock).

Source: Straying		
Criteria	Probability	Notes
Hatchery fish will be reared to release size in the watershed targeted for supplementation or reintroduction.	H	Incubation and rearing facilities located in watershed.
Hatchery fish will be marked to provide effective estimation of straying.	H	Staff and equipment exist to mark all releases with adipose fin clip. USFWS will fund marking for duration of project.
Adjacent spawning populations will be effectively monitored to detect straying.	H	Adjacent spawning populations are monitored on regular basis.

Hazard VI: Masking of Population Status

Criteria	Probability	Notes
A sufficient proportion of hatchery fish are marked to estimate hatchery/wild ratios on the spawning grounds.	H	The intent is to mark all released fish with adipose fin clip.
Sufficient wild spawning areas are surveyed to estimate hatchery/wild ratios accurately.	H	Adjacent spawning areas are regularly surveyed index streams.
Proportion of hatchery fish on spawning grounds is (or will be) less than 5-15% **OR** Hatchery program will be of short duration (3 generations equal to 12 years) **OR** Returning hatchery fish will spawn primarily in habitat currently underutilized by natural spawners of the same species.	H	Project is of short duration.

Salmon Creek Project

Hazard I: Hatchery Failure

Criteria	Probability	Notes
Hatchery personnel live on-site to allow rapid response to water source or power failures.	M	Eggs are incubated at Dungeness Hatchery with on-station 24 hour personnel. Water source at rearing facility in Salmon Creek watershed is reasonably secure.
Low pressure/low water alarms functioning for water supplies serving summer chum incubation and rearing areas.	H	Alarm system is in place at Dungeness Hatchery and at Salmon Creek facility.
All hatchery personnel responsible for rearing fish trained in standard fish propagation and fish health methods.	H	Experienced volunteers supervised by trained WDFW staff.
Incubation and rearing facilities are sited in areas that are not prone to flooding.	H	Facilities are located in areas of low flooding risk.

Hazard II: Ecological Effects

Criteria	Probability	Notes
Propagated summer chum are released at a life stage (1 gram fed fry) and time (March-April) that will reduce the risk of predation and competition effects on wild fish.	H	Capability has been demonstrated at site.
Summer chum are reared to release size on ground or surface water within the watershed targeted for supplementation or reintroduction.	H	Surface water source within watershed for rearing lifestage.
Fish health practices developed by the co-managers are applied in all hatchery activities to minimize the risk of fish disease occurrence, transmittal, and catastrophic loss.	H	WDFW staff support ensures proper procedures and treatment.

Hazard III: Reduction in Effective Population Size

Criteria	Probability	Notes
Hatchery fish are marked to accurately estimate proportion of hatchery fish spawning naturally in target population and proportion of wild fish spawning in hatchery.	H	Funding, equipment and staff are available to otolith mark all releases.
Natural spawning is regularly monitored to accurately estimate the proportion of hatchery fish spawning in target population.	H	Funding, equipment and staff are available to sample, read and analyze otoliths of spawning population.
In the target population, the proportion of natural spawners that are hatchery fish is approximately equal to the proportion of wild fish that were taken into the hatchery the previous generation **OR** In the target population, the proportion of natural spawners that are hatchery-origin fish is larger than the proportion of wild fish that were taken into the hatchery the previous generation **AND** the wild	M	The proportion of natural spawners that are hatchery-origin fish is unknown at this time. Spawners are being sampled and an estimate of the proportion should be forthcoming. There is some risk that the hatchery-origin proportion exceeds the proportion of spawners taken for hatchery production in the previous

Hazard III: Reduction in Effective Population Size (cont.)

population is increasing in abundance at a rate at least equal to the proportion of naturally spawning hatchery-origin fish **OR** The target wild population is believed to be in substantial danger of extinction within the next 35 years **AND** the effective number of breeders in the hatchery is as large as possible given the available broodstock. **OR** The project is to reintroduce fish to a location removed from the target population with likelihood of less than 5-15% return to target population.		generation.

Hazard IV: Loss of Within Population Diversity

Source: Broodstock selection		
Criteria	Probability	Notes
Broodstock source is not already substantially domesticated.	H	Project begun with brood year 1992.

Source: Broodstock collection		
Distributions of morphological, behavioral or life-history traits (e.g. run or spawn timing, size, appearance, age structure, etc) will be collected for target population.	H	Trained staff and supervised volunteers will record pertinent biological data.
Multi-trait distribution of broodstock sample closely matches the multi-trait distribution of target population (e.g. similar run and spawn timing, size, appearance, age structure, etc).	H	Location, timing and protocol of collection indicates matching.
Collection is technically and logistically possible (e.g. site is accessible throughout run, weirs have reasonable chance of continuous operation throughout season, necessary staff are available to carry out collection, funding is available to measure traits, etc).	H	Demonstrated successful collection at permanent weir.
The effective population size will be maintained by collecting a minimum of 50 pairs except where the total population is less than 100 fish.	H	Yes. Meeting criterion is ensured by collection at weir.

Source: Mating, rearing and release methods (degree of difference between wild and hatchery environments and duration)		
The minimum standard for matings will be one male per female.	H	One to one matings are used.
Mating and rearing methods are similar enough to those observed in the wild to avoid substantial domestication selection pressure **OR** Hatchery program will be of short duration (3 generations equal to 12 years)	H	Project to be of short duration - not to exceed 12 years.

Source: Mating, rearing and release methods (degree of difference between wild and hatchery environments and duration) (cont.)		
OR The proportion of natural spawners that are hatchery-origin fish in the target population is less than 5-15%.		
Hatchery progeny will be released at essentially the same sizes and life-history stages as observed in the target population at the time of release **OR** Hatchery program will be of short duration (3 generations) **OR** The proportion of natural spawners that are hatchery-origin fish in the target population is less than 5-15%.	H	Hatchery progeny to reared to 1 gram size before release; however, program will be of short duration.

Source: Hatchery-induced genetic swamping (Ryman-Laikre effect)		
Broodstocking does not collect a small fraction of the spawner population and, through use of hatchery operation, generate a subsequent large proportion of the natural spawning population.	H	Meeting criterion is ensured by collection at weir.

Hazard V: Loss of Among Population Diversity

Source of hazard: Broodstock selection		
Criteria	Probability	Notes
All the discrete populations within the watershed containing the target population have been correctly identified.	H	Total accessible area within watershed surveyed since mid-70s.
Selected broodstock source is substantially genetically similar to target population.	H	Broodstock source is target population.
Broodstock used for direct reintroduction is used only for one site.	H	Only one direct reintroduction site, separate from Snow/Salmon stock, is being used - Chimacum.

Source: Broodstock collection		
Criteria	Probability	Notes
It will be possible to collect at a location and time such that only the target population will be collected.	H	Only target population exists in watershed.

Source: Straying		
Criteria	Probability	Notes
Hatchery fish will be reared to release size in the watershed targeted for supplementation or reintroduction.	H	Rearing facilities located in watershed.
Hatchery fish will be marked to provide effective estimation of straying.	H	Staff, equipment and funding exist to otolith mark all released fish.
Adjacent spawning populations will be effectively monitored to detect straying.	M	Funding and resources have not been secured for otolith sampling, reading and analysis of other watersheds.

Hazard VI: Masking of Population Status

Criteria	Probability	Notes
A sufficient proportion of hatchery fish are marked to estimate hatchery/wild ratios on the spawning grounds.	H	All released fish will be otolith marked.
Sufficient wild spawning areas are surveyed to estimate hatchery/wild ratios accurately.	H	Funding, equipment and staff are available to sample, read and analyze otoliths of spawning population.
Proportion of hatchery fish on spawning grounds is (or will be) less than 5-15% **OR** Hatchery program will be of short duration (3 generations equal to 12 years) **OR** Returning hatchery fish will spawn primarily in habitat currently underutilized by natural spawners of the same species.	H	Project is of short duration.

Jimmycomelately Project

Hazard I: Hatchery Failure

Criteria	Probability	Notes
Hatchery personnel live on-site to allow rapid response to water source or power failures.	M	Site and personnel undetermined.
Low pressure/low water alarms functioning for water supplies serving summer chum incubation and rearing areas.	M	Specific project design not yet determined.
All hatchery personnel responsible for rearing fish trained in standard fish propagation and fish health methods.	H	Expect experienced volunteers and trained WDFW staff support.
Incubation and rearing facilities are sited in areas that are not prone to flooding.	M	Expect to site project with low risk of flooding.

Hazard II: Ecological Effects

Criteria	Probability	Notes
Propagated summer chum are released at a life stage (1 gram fed fry) and time (March-April) that will reduce the risk of predation and competition effects on wild fish.	H	Will be key design element..
Summer chum are reared to release size on ground or surface water within the watershed targeted for supplementation or reintroduction.	H	Water source would be within watershed.
Fish health practices developed by the co-managers are applied in all hatchery activities to minimize the risk of fish disease occurrence, transmittal, and catastrophic loss.	H	Expected WDFW staff support would ensure proper procedures and treatment.

Hazard III: Reduction in Effective Population Size

Criteria	Probability	Notes
Hatchery fish are marked to accurately estimate proportion of hatchery fish spawning naturally in target population and proportion of wild fish spawning in hatchery.	H	Expected to be key element to plan for operations.
Natural spawning is regularly monitored to accurately estimate the proportion of hatchery fish spawning in target population.	M	Expected to be key element to plan for operations.
In the target population, the proportion of natural spawners that are hatchery fish is approximately equal to the proportion of wild fish that were taken into the hatchery the previous generation **OR** In the target population, the proportion of natural spawners that are hatchery-origin fish is larger than the proportion of wild fish that were taken into the hatchery the previous generation **AND** the wild population is increasing in abundance at a rate at least equal to the proportion of naturally spawning	M	Broodstock is believed to be at high risk of extinction. Expect to collect as many breeders as possible given the available broodstock.

Hazard III: Reduction in Effective Population Size (cont.)

hatchery-origin fish **OR** **The target wild population is believed to be in substantial danger of extinction within the next 35 years AND the effective number of breeders in the hatchery is as large as possible given the available broodstock.** **OR** The project is to reintroduce fish to a location removed from the target population with likelihood of less than 5-15% return to target population.		

Hazard IV: Loss of Within Population Diversity

Source: Broodstock selection		
Criteria	Probability	Notes
Broodstock source is not already substantially domesticated.	H	Broodstock has not previously been propagated.

Source: Broodstock collection		
Distributions of morphological, behavioral or life-history traits (e.g. run or spawn timing, size, appearance, age structure, etc) will be collected for target population.	H	Trained staff will record pertinent biological data.
Multi-trait distribution of broodstock sample closely matches the multi-trait distribution of target population (e.g. similar run and spawn timing, size, appearance, age structure, etc).	M	Broodstock collection parameters unknown but key element will be to obtain close match to target population.
Collection is technically and logistically possible (e.g. site is accessible throughout run, weirs have reasonable chance of continuous operation throughout season, necessary staff are available to carry out collection, funding is available to measure traits, etc).	M	Unknown but will be key element of project.
The effective population size will be maintained by collecting a minimum of 50 pairs except where the total population is less than 100 fish.	M	Criterion will be incorporated in plan.

Source: Mating, rearing and release methods (degree of difference between wild and hatchery environments and duration)		
The minimum standard for matings will be one male per female.	H	One to one or factorial matings will be a project objective.
Mating and rearing methods are similar enough to those observed in the wild to avoid substantial domestication selection pressure **OR** Hatchery program will be of short duration (3 generations equal to 12 years) **OR** The proportion of natural spawners that are hatchery-origin fish in the target population is less than 5-15%.	H	Project will be of short duration - not to exceed 12 years.

Source: Mating, rearing and release methods (degree of difference between wild and hatchery environments and duration) (cont.)		
Hatchery progeny will be released at essentially the same sizes and life-history stages as observed in the target population at the time of release **OR** Hatchery program will be of short duration (3 generations) **OR** The proportion of natural spawners that are hatchery-origin fish in the target population is less than 5-15%.	H	Hatchery progeny to reared to 1 gram size before release; however, program will be of short duration.

Source: Hatchery-induced genetic swamping (Ryman-Laikre effect)		
Broodstocking does not collect a small fraction of the spawner population and, through use of hatchery operation, generate a subsequent large proportion of the natural spawning population.	M	Broodstocking limitations are unknown but avoiding this effect will be a key element of project.

Hazard V: Loss of Among Population Diversity

Source of hazard: Broodstock selection		
Criteria	Probability	Notes
All the discrete populations within the watershed containing the target population have been correctly identified.	H	Total accessible area within watershed surveyed since 1982.
Selected broodstock source is substantially genetically similar to target population.	H	Broodstock source is target population.
Broodstock used for direct reintroduction is used only for one site.	N.A.	

Source: Broodstock collection		
Criteria	Probability	Notes
It will be possible to collect at a location and time such that only the target population will be collected.	H	Only target population exists in watershed.

Source: Straying		
Criteria	Probability	Notes
Hatchery fish will be reared to release size in the watershed targeted for supplementation or reintroduction.	H	Location of facilities in watershed will be key element of project.
Hatchery fish will be marked to provide effective estimation of straying.	H	Fish will be marked to differentiate hatchery-origin and natural-origin spawners within watershed.
Adjacent spawning populations will be effectively monitored to detect straying.	L	Undetermined at this time.

Hazard VI: Masking of Population Status

Criteria	Probability	Notes
A sufficient proportion of hatchery fish are marked to estimate hatchery/wild ratios on the spawning grounds.	H	Expect to provide for adequate marking.
Sufficient wild spawning areas are surveyed to estimate hatchery/wild ratios accurately.	M	Expect would be key element to plan for operations.
Proportion of hatchery fish on spawning grounds is (or will be) less than 5-15%. **OR** Hatchery program will be of short duration (3 generations equal to 12 years) **OR** Returning hatchery fish will spawn primarily in habitat currently underutilized by natural spawners of the same species.	H	Returning hatchery-origin fish will spawn in habitat currently under-utilized and project is of short duration.

Dungeness Project

Hazard I: Hatchery Failure

Criteria	Probability	Notes
Hatchery personnel live on-site to allow rapid response to water source or power failures.	M	On-site living is possibility if existing hatchery facilities used.
Low pressure/low water alarms functioning for water supplies serving summer chum incubation and rearing areas.	M	Alarm system exists if existing hatchery facilities are used.
All hatchery personnel responsible for rearing fish trained in standard fish propagation and fish health methods.	H	Expect experienced volunteers and trained WDFW staff support.
Incubation and rearing facilities are sited in areas that are not prone to flooding.	M	Undetermined but expect to site project with low risk of flooding.

Hazard II: Ecological Effects

Criteria	Probability	Notes
Propagated summer chum are released at a life stage (1 gram fed fry) and time (March-April) that will reduce the risk of predation and competition effects on wild fish.	H	Would be key design element.
Summer chum are reared to release size on ground or surface water within the watershed targeted for supplementation or reintroduction.	H	Water source would be within watershed.
Fish health practices developed by the co-managers are applied in all hatchery activities to minimize the risk of fish disease occurrence, transmittal, and catastrophic loss.	H	Expected WDFW staff support would ensure proper procedures and treatment.

Hazard III: Reduction in Effective Population Size

Criteria	Probability	Notes
Hatchery fish are marked to accurately estimate proportion of hatchery fish spawning naturally in target population and proportion of wild fish spawning in hatchery.	H	Expect would be key element to plan for operations.
Natural spawning is regularly monitored to accurately estimate the proportion of hatchery fish spawning in target population.	M	Expect would be key element to plan for operations.
In the target population, the proportion of natural spawners that are hatchery fish is approximately equal to the proportion of wild fish that were taken into the hatchery the previous generation **OR** In the target population, the proportion of natural spawners that are hatchery-origin fish is larger than the proportion of wild fish that were taken into the hatchery the previous generation **AND** the wild population is increasing in abundance at a rate at least equal to the proportion of naturally spawning hatchery-origin fish	L	The population status is unknown.

Hazard III: Reduction in Effective Population Size (cont.)

OR The target wild population is believed to be in substantial danger of extinction within the next 35 years **AND** the effective number of breeders in the hatchery is as large as possible given the available broodstock. **OR** The project is to reintroduce fish to a location removed from the target population with likelihood of less than 5-15% return to target population.		

Hazard IV: Loss of Within Population Diversity

Source: Broodstock selection		
Criteria	Probability	Notes
Broodstock source is not already substantially domesticated.	H	Dungeness stock has never been propagated.

Source: Broodstock collection		
Distributions of morphological, behavioral or life-history traits (e.g. run or spawn timing, size, appearance, age structure, etc) will be collected for target population.	H	Trained staff would record pertinent biological data.
Multi-trait distribution of broodstock sample closely matches the multi-trait distribution of target population (e.g. similar run and spawn timing, size, appearance, age structure, etc).	M	Broodstock collection parameters unknown but key element would be to obtain close match to target population.
Collection is technically and logistically possible (e.g. site is accessible throughout run, weirs have reasonable chance of continuous operation throughout season, necessary staff are available to carry out collection, funding is available to measure traits, etc).	M	Unknown but would be key element of project.
The effective population size will be maintained by collecting a minimum of 50 pairs except where the total population is less than 100 fish.	M	Criterion would be incorporated in plan.

Source: Mating, rearing and release methods (degree of difference between wild and hatchery environments and duration)		
The minimum standard for matings will be one male per female.	H	One to one or factorial matings would be project objective.
Mating and rearing methods are similar enough to those observed in the wild to avoid substantial domestication selection pressure **OR** Hatchery program will be of short duration (3 generations equal to 12 years) **OR** The proportion of natural spawners that are hatchery-origin fish in the target population is less than 5-15%.	H	Project will be of short duration - not to exceed 12 years.

Source: Mating, rearing and release methods (degree of difference between wild and hatchery environments and duration) (cont.)		
Hatchery progeny will be released at essentially the same sizes and life-history stages as observed in the target population at the time of release **OR** Hatchery program will be of short duration (3 generations) **OR** The proportion of natural spawners that are hatchery-origin fish in the target population is less than 5-15%.	H	Hatchery progeny to be reared to 1 gram size before release; however, program will be of short duration.

Source: Hatchery-induced genetic swamping (Ryman-Laikre effect)		
Broodstocking does not collect a small fraction of the spawner population and, through use of hatchery operation, generate a subsequent large proportion of the natural spawning population.	M	Broodstocking limitations are unknown but avoiding this effect will be a key element of project.

Hazard V: Loss of Among Population Diversity

Source of hazard: Broodstock selection		
Criteria	Probability	Notes
All the discrete populations within the watershed containing the target population have been correctly identified.	L	Population status is unknown.
Selected broodstock source is substantially genetically similar to target population.	M	Lack knowledge about stock but likely to be true.
Broodstock used for direct reintroduction is used only for one site.	M	Uncertain. Broodstock source depends on undetermined stock status.

Source: Broodstock collection		
Criteria	Probability	Notes
It will be possible to collect at a location and time such that only the target population will be collected.	M	Undetermined since population status and broodstock source are unknown.

Source: Straying		
Criteria	Probability	Notes
Hatchery fish will be reared to release size in the watershed targeted for supplementation or reintroduction.	H	Locating facilities in watershed would be key element of project.
Hatchery fish will be marked to provide effective estimation of straying.	H	Fish would be marked to differentiate hatchery-origin and natural-origin spawners within watershed.
Adjacent spawning populations will be effectively monitored to detect straying.	L	Undetermined at this time.

Hazard VI: Masking of Population Status

Criteria	Probability	Notes
A sufficient proportion of hatchery fish are marked to estimate hatchery/wild ratios on the spawning grounds.	H	Expect to provide for adequate marking.
Sufficient wild spawning areas are surveyed to estimate hatchery/wild ratios accurately.	M	Expect would be key element to plan for operations.
Proportion of hatchery fish on spawning grounds is (or will be) less than 5-15% **OR** Hatchery program will be of short duration (3 generations equal to 12 years) **OR** Returning hatchery fish will spawn primarily in habitat currently underutilized by natural spawners of the same species.	H	Returning hatchery fish will spawn in habitat currently underutilized by target population and project will be of short duration.

Big Beef Project

Hazard I: Hatchery Failure

Criteria	Probability	Notes
Hatchery personnel live on-site to allow rapid response to water source or power failures.	H	Hatchery personnel live on-site.
Low pressure/low water alarms functioning for water supplies serving summer chum incubation and rearing areas.	H	Functioning alarm system in place.
All hatchery personnel responsible for rearing fish trained in standard fish propagation and fish health methods.	H	Experienced volunteers. Trained WDFW staff support.
Incubation and rearing facilities are sited in areas that are not prone to flooding.	M	Facilities location is currently at moderate risk of flooding.

Hazard II: Ecological Effects

Criteria	Probability	Notes
Propagated summer chum are released at a life stage (1 gram fed fry) and time (March-April) that will reduce the risk of predation and competition effects on wild fish.	H	Capability has been demonstrated at site.
Summer chum are reared to release size on ground or surface water within the watershed targeted for supplementation or reintroduction.	H	Ground water source within watershed.
Fish health practices developed by the co-managers are applied in all hatchery activities to minimize the risk of fish disease occurrence, transmittal, and catastrophic loss.	H	WDFW staff support ensures proper procedures and treatment.

Hazard III: Reduction in Effective Population Size

Criteria	Probability	Notes
Hatchery fish are marked to accurately estimate proportion of hatchery fish spawning naturally in target population and proportion of wild fish spawning in hatchery.	H	Funding, equipment and staff are available to otolith mark all releases.
Natural spawning are regularly monitored to accurately estimate the proportion of hatchery fish spawning in target population.	H	Funding, equipment and staff are available to sample, read and evaluate results of otolith samples from spawning population.
In the target population, the proportion of natural spawners that are hatchery fish is approximately equal to the proportion of wild fish that were taken into the hatchery the previous generation **OR** In the target population, the proportion of natural spawners that are hatchery-origin fish is larger than the proportion of wild fish that were taken into the hatchery the previous generation **AND** the wild population is increasing in abundance at a rate at least equal to the proportion of naturally spawning	H	The project is to reintroduce summer chum to Big Beef Creek using broodstock from the Big Quilcene / Little Quilcene stock. Big Beef Creek is sufficiently removed from the Big and Little Quilcene rivers that the likelihood of returns to the donor stock watersheds from releases at Big Beef Creek is small.

Hazard III: Reduction in Effective Population Size (cont.)

hatchery-origin fish **OR** The target wild population is believed to be in substantial danger of extinction within the next 35 years **AND** the effective number of breeders in the hatchery is as large as possible given the available broodstock **OR** **The project is to reintroduce fish to a location removed from the target population with likelihood of less than 5-15% return to target population.**		

Hazard IV: Loss of Within Population Diversity

Source: Broodstock selection		
Criteria	Probability	Notes
Broodstock source is not already substantially domesticated.	H	Quilcene in-river broodstocking began 1992.

Source: Broodstock collection		
Distributions of morphological, behavioral or life-history traits (e.g. run or spawn timing, size, appearance, age structure, etc) will be collected for target population.	M	Trained staff records pertinent biological data but required collection procedure (in Quilcene Bay) limits trait assessment.
Multi-trait distribution of broodstock sample closely matches the multi-trait distribution of target population (e.g. similar run and spawn timing, size, appearance, age structure, etc).	M	Collection procedure limits trait assessment.
Collection is technically and logistically possible (e.g. site is accessible throughout run, weirs have reasonable chance of continuous operation throughout season, necessary staff are available to carry out collection, funding is available to measure traits, etc).	H	Demonstrated success with broodstock source at Quilcene.
The effective population size will be maintained by collecting a minimum of 50 pairs except where the total population is less than 100 fish.	H	Again, demonstrated success.

Source: Mating, rearing and release methods (degree of difference between wild and hatchery environments and duration)		
The minimum standard for matings will be one male per female.	H	Successfully implemented with Quilcene Project.
Mating and rearing methods are similar enough to those observed in the wild to avoid substantial domestication selection pressure **OR** Hatchery program will be of short duration (3 generations equal to 12 years) **OR**	H	Project to be of short duration - not to exceed 12 years.

Source: Mating, rearing and release methods (degree of difference between wild and hatchery environments and duration) (cont.)		
The proportion of natural spawners that are hatchery-origin fish in the target population is less than 5-15%.		
Hatchery progeny will be released at essentially the same sizes and life-history stages as observed in the target population at the time of release **OR** Hatchery program will be of short duration (3 generations) **OR** The proportion of natural spawners that are hatchery-origin fish in the target population is less than 5-15%.	H	Hatchery progeny to reared to 1 gram size before release; however, program will be of short duration.

Source: Hatchery-induced genetic swamping (Ryman-Laikre effect)		
Broodstocking does not collect a small fraction of the spawner population and, through use of hatchery operation, generate a subsequent large proportion of the natural spawning population.	H	Demonstrated success with broodstock source at Quilcene.

Hazard V: Loss of Among Population Diversity

Source of hazard: Broodstock selection		
Criteria	Probability	Notes
All the discrete populations within the watershed containing the target population have been correctly identified.	H	Total accessible area within watershed surveyed since mid-70s.
Selected broodstock source is substantially genetically similar to target population.	H	Broodstock source is target population.
Broodstock used for direct reintroduction is used only for one site.	H	Big Beef is only reintroduction project using Quilcene broodstock.

Source: Broodstock collection		
Criteria	Probability	Notes
It will be possible to collect at a location and time such that only the target population will be collected.	H	Only target population exists in watershed.

Source: Straying		
Criteria	Probability	Notes
Hatchery fish will be reared to release size in the watershed targeted for supplementation or reintroduction.	H	Rearing facilities located in watershed.
Hatchery fish will be marked to provide effective estimation of straying.	H	Staff, equipment and funding exist to otolith mark all releases.
Adjacent spawning populations will be effectively monitored to detect straying.	L	Undetermined at this time.

Hazard VI: Masking of Population Status

Criteria	Probability	Notes
A sufficient proportion of hatchery fish are marked to estimate hatchery/wild ratios on the spawning grounds.	H	All releases will be otolith marked.
Sufficient wild spawning areas are surveyed to estimate hatchery/wild ratios accurately.	H	Funding, equipment and staff are available to sample, read and evaluate results of otolith samples from spawning population.
Proportion of hatchery fish on spawning grounds is (or will be) less than 5-15% **OR** Hatchery program will be of short duration (3 generations equal to 12 years) **OR** Returning hatchery fish will spawn primarily in habitat currently underutilized by natural spawners of the same species.	H	Returning hatchery fish will spawn in habitat currently not being utilized and project is of short duration.

Chimacum Project

Hazard I: Hatchery Failure

Criteria	Probability	Notes
Hatchery personnel live on-site to allow rapid response to water source or power failures.	M	Eggs are incubated at Dungeness Hatchery with on-station 24 hour personnel. Water source at rearing facility in Chimacum Creek watershed is reasonably secure.
Low pressure/low water alarms functioning for water supplies serving summer chum incubation and rearing areas.	H	Alarm system is in place at Dungeness Hatchery and at Chimacum Creek facility.
All hatchery personnel responsible for rearing fish trained in standard fish propagation and fish health methods.	H	Experienced volunteers supervised by trained WDFW staff.
Incubation and rearing facilities are sited in areas that are not prone to flooding.	H	Facilities are located in area of low flooding risk.

Hazard II: Ecological Effects

Criteria	Probability	Notes
Propagated summer chum are released at a life stage (1 gram fed fry) and time (March-April) that will reduce the risk of predation and competition effects on wild fish.	H	Capability has been demonstrated at site.
Summer chum are reared to release size on ground or surface water within the watershed targeted for supplementation or reintroduction.	H	Surface water source within watershed for rearing lifestage.
Fish health practices developed by the co-managers are applied in all hatchery activities to minimize the risk of fish disease occurrence, transmittal, and catastrophic loss.	H	WDFW staff support ensures proper procedures and treatment.

Hazard III: Reduction in Effective Population Size

Criteria	Probability	Notes
Hatchery fish are marked to accurately estimate proportion of hatchery fish spawning naturally in target population and proportion of wild fish spawning in hatchery.	H	Funding, equipment and staff are available to otolith mark all releases.
Natural spawning is regularly monitored to accurately estimate the proportion of hatchery fish spawning in target population.	M	Intent is to sample, read and analyze otoliths of spawning population, but funding and resources have not yet been secured.
In the target population, the proportion of natural spawners that are hatchery fish is approximately equal to the proportion of wild fish that were taken into the hatchery the previous generation **OR** In the target population, the proportion of natural spawners that are hatchery-origin fish is larger than the proportion of wild fish that were taken into the	H	The project is to reintroduce summer chum to Chimacum Creek using broodstock from Salmon Creek. Chimacum Creek is sufficiently removed from Salmon Creek that few or no adult returns to Salmon Creek are expected.

Hazard III: Reduction in Effective Population Size (cont.)

hatchery the previous generation **AND** the wild population is increasing in abundance at a rate at least equal to the proportion of naturally spawning hatchery-origin fish **OR** The target wild population is believed to be in substantial danger of extinction within the next 35 years **AND** the effective number of breeders in the hatchery is as large as possible given the available broodstock. **OR** **The project is to reintroduce fish to a location removed from the target population with likelihood of less than 5-15% return to target population**.		

Hazard IV: Loss of Within Population Diversity

Source: Broodstock selection		
Criteria	Probability	Notes
Broodstock source is not already substantially domesticated.	H	Salmon Creek broodstocking began 1992.

Source: Broodstock collection		
Distributions of morphological, behavioral or life-history traits (e.g. run or spawn timing, size, appearance, age structure, etc) will be collected for target population.	H	Trained staff and supervised volunteers record pertinent biological data.
Multi-trait distribution of broodstock sample closely matches the multi-trait distribution of target population (e.g. similar run and spawn timing, size, appearance, age structure, etc).	H	Location, timing and protocol of collection indicates matching.
Collection is technically and logistically possible (e.g. site is accessible throughout run, weirs have reasonable chance of continuous operation throughout season, necessary staff are available to carry out collection, funding is available to measure traits, etc).	H	Demonstrated success with broodstock source at Salmon Creek.
The effective population size will be maintained by collecting a minimum of 50 pairs except where the total population is less than 100 fish.	H	Again, demonstrated success.

Source: Mating, rearing and release methods (degree of difference between wild and hatchery environments and duration)		
The minimum standard for matings will be one male per female.	H	Successfully implemented with Salmon Creek Project.
Mating and rearing methods are similar enough to those observed in the wild to avoid substantial domestication selection pressure **OR**	H	Project to be of short duration - not to exceed 12 years.

Source: Mating, rearing and release methods (degree of difference between wild and hatchery environments and duration) (cont.)		
Hatchery program will be of short duration (3 generations equal to 12 years) **OR** The proportion of natural spawners that are hatchery-origin fish in the target population is less than 5-15%.		
Hatchery progeny will be released at essentially the same sizes and life-history stages as observed in the target population at the time of release **OR** Hatchery program will be of short duration (3 generations) **OR** The proportion of natural spawners that are hatchery-origin fish in the target population is less than 5-15%.	H	Hatchery progeny to reared to 1 gram size before release; however, program will be of short duration.

Source: Hatchery-induced genetic swamping (Ryman-Laikre effect)		
Broodstocking does not collect a small fraction of the spawner population and, through use of hatchery operation, generate a subsequent large proportion of the natural spawning population.	H	Demonstrated success with broodstock source at Salmon Creek.

Hazard V: Loss of Among Population Diversity

Source of hazard: Broodstock selection		
Criteria	Probability	Notes
All the discrete populations within the watershed containing the target population have been correctly identified.	H	Total accessible area within watershed surveyed since mid-70s.
Selected broodstock source is substantially genetically similar to target population.	H	Broodstock source is target population.
Broodstock used for direct reintroduction is used only for one site.	H	Chimacum is only reintroduction project using Salmon/Snow broodstock.

Source: Broodstock collection		
Criteria	Probability	Notes
It will be possible to collect at a location and time such that only the target population will be collected.	H	Only target population exists in donor population's (Salmon Creek) watershed.

Source: Straying		
Criteria	Probability	Notes
Hatchery fish will be reared to release size in the watershed targeted for supplementation or reintroduction.	H	Rearing facilities located in watershed.

Source: Straying (cont.)		
Hatchery fish will be marked to provide effective estimation of straying.	H	Staff, equipment and funding exist to otolith mark all released fish.
Adjacent spawning populations will be effectively monitored to detect straying.	L	Funding and resources have not been secured for otolith sampling, reading and analysis.

Hazard VI: Masking of Population Status

Criteria	Probability	Notes
A sufficient proportion of hatchery fish are marked to estimate hatchery/wild ratios on the spawning grounds.	H	All released fish will be otolith marked.
Sufficient wild spawning areas are surveyed to estimate hatchery/wild ratios accurately.	M	Funding and resources have not yet been secured for otolith sampling, reading and analysis.
Proportion of hatchery fish on spawning grounds is (or will be) less than 5-15% **OR** Hatchery program will be of short duration (3 generations equal to 12 years) **OR** Returning hatchery fish will spawn primarily in habitat currently underutilized by natural spawners of the same species.	H	Project is of short duration.

Tahuya Project

Hazard I: Hatchery Failure

Criteria	Probability	Notes
Hatchery personnel live on-site to allow rapid response to water source or power failures.	M	Site and personnel undetermined.
Low pressure/low water alarms functioning for water supplies serving summer chum incubation and rearing areas.	M	Specific project design not yet determined.
All hatchery personnel responsible for rearing fish trained in standard fish propagation and fish health methods.	H	Expect experienced volunteers and trained WDFW staff support.
Incubation and rearing facilities are sited in areas that are not prone to flooding.	M	Expect to site project at site with low risk of flooding.

Hazard II: Ecological Effects

Criteria	Probability	Notes
Propagated summer chum are released at a life stage (1 gram fed fry) and time (March-April) that will reduce the risk of predation and competition effects on wild fish.	H	Will be key design element.
Summer chum are reared to release size on ground or surface water within the watershed targeted for supplementation or reintroduction.	H	Water source would be within watershed.
Fish health practices developed by the co-managers are applied in all hatchery activities to minimize the risk of fish disease occurrence, transmittal, and catastrophic loss.	H	Expected WDFW staff support would ensure proper procedures and treatment.

Hazard III: Reduction in Effective Population Size

Criteria	Probability	Notes
Hatchery fish are marked to accurately estimate proportion of hatchery fish spawning naturally in target population and proportion of wild fish spawning in hatchery.	H	Expect to be key element to plan for operations.
Natural spawning is regularly monitored to accurately estimate the proportion of hatchery fish spawning in target population.	M	Expect to be key element to plan for operations.
In the target population, the proportion of natural spawners that are hatchery fish is approximately equal to the proportion of wild fish that were taken into the hatchery the previous generation **OR** In the target population, the proportion of natural spawners that are hatchery-origin fish is larger than the proportion of wild fish that were taken into the hatchery the previous generation **AND** the wild population is increasing in abundance at a rate at least equal to the proportion of naturally spawning hatchery-origin fish	M	Broodstock undetermined but key project design element will be to find appropriate broodstock. Alternatives to be considered would be sufficiently removed from Tahuya River that expected adult returns from project to donor population would be few or none.

Hazard III: Reduction in Effective Population Size (cont.)

OR The target wild population is believed to be in substantial danger of extinction within the next 35 years **AND** the effective number of breeders in the hatchery is as large as possible given the available broodstock. **OR** **The project is to reintroduce fish to a location removed from the target population with likelihood of less than 5-15% return to target population.**		

Hazard IV: Loss of Within Population Diversity

Source: Broodstock selection		
Criteria	Probability	Notes
Broodstock source is not already substantially domesticated.	H	Broodstock undetermined but unlikely to be domesticated.

Source: Broodstock collection		
Distributions of morphological, behavioral or life-history traits (e.g. run or spawn timing, size, appearance, age structure, etc) will be collected for target population.	M	Expect trained staff will record pertinent biological data.
Multi-trait distribution of broodstock sample closely matches the multi-trait distribution of target population (e.g. similar run and spawn timing, size, appearance, age structure, etc).	M	Broodstock collection parameters unknown but key element will be to obtain close match to target population.
Collection is technically and logistically possible (e.g. site is accessible throughout run, weirs have reasonable chance of continuous operation throughout season, necessary staff are available to carry out collection, funding is available to measure traits, etc).	M	Unknown but will be key element of project.
The effective population size will be maintained by collecting a minimum of 50 pairs except where the total population is less than 100 fish.	M	Criterion will be incorporated in plan.

Source: Mating, rearing and release methods (degree of difference between wild and hatchery environments and duration)		
The minimum standard for matings will be one male per female.	M	One to one or factorial matings will be a project objective.
Mating and rearing methods are similar enough to those observed in the wild to avoid substantial domestication selection pressure **OR** Hatchery program will be of short duration (3 generations equal to 12 years) **OR** The proportion of natural spawners that are hatchery-origin fish in the target population is less than 5-15%.	H	Project will be of short duration - not to exceed 12 years.

Source: Mating, rearing and release methods (degree of difference between wild and hatchery environments and duration) (cont.)		
Hatchery progeny will be released at essentially the same sizes and life-history stages as observed in the target population at the time of release **OR** Hatchery program will be of short duration (3 generations) **OR** The proportion of natural spawners that are hatchery-origin fish in the target population is less than 5-15%.	H	Hatchery progeny to reared to 1 gram size before release; however, program will be of short duration.

Source: Hatchery-induced genetic swamping (Ryman-Laikre effect)		
Broodstocking does not collect a small fraction of the spawner population and, through use of hatchery operation, generate a subsequent large proportion of the natural spawning population.	M	Broodstocking limitations undetermined but key element of project will be to avoid this effect.

Hazard V: Loss of Among Population Diversity

Source of hazard: Broodstock selection		
Criteria	Probability	Notes
All the discrete populations within the watershed containing the target population have been correctly identified.	H	Unknown broodstock source but expect to meet criterion.
Selected broodstock source is substantially genetically similar to target population.	H	Broodstock source will be target population.
Broodstock used for direct reintroduction is used only for one site.	H	General requirement for all projects.

Source: Broodstock collection		
Criteria	Probability	Notes
It will be possible to collect at a location and time such that only the target population will be collected.	H	Broodstock undetermined at this time but expect to meet criterion.

Source: Straying		
Criteria	Probability	Notes
Hatchery fish will be reared to release size in the watershed targeted for supplementation or reintroduction.	H	Location of facilities in watershed will be key element of project.
Hatchery fish will be marked to provide effective estimation of straying.	H	Fish will be marked to differentiate hatchery-origin and natural-origin spawners within watershed.
Adjacent spawning populations will be effectively monitored to detect straying.	L	Undetermined at this time.

Hazard VI: Masking of Population Status

Criteria	Probability	Notes
A sufficient proportion of hatchery fish are marked to estimate hatchery/wild ratios on the spawning grounds.	H	Expect to provide for adequate marking.
Sufficient wild spawning areas are surveyed to estimate hatchery/wild ratios accurately.	M	Expect would be key element to plan for operations.
Proportion of hatchery fish on spawning grounds is (or will be) less than 5-15% **OR** Hatchery program will be of short duration (3 generations equal to 12 years) **OR** Returning hatchery fish will spawn primarily in habitat currently underutilized by natural spawners of the same species.	H	Returning hatchery-origin fish will spawn in habitat currently not utilized and project would be of short duration.

Dewatto Project

Hazard I: Hatchery Failure

Criteria	Probability	Notes
Hatchery personnel live on-site to allow rapid response to water source or power failures.	M	Site and personnel undetermined.
Low pressure/low water alarms functioning for water supplies serving summer chum incubation and rearing areas.	M	Specific project design not yet determined.
All hatchery personnel responsible for rearing fish trained in standard fish propagation and fish health methods.	H	Expect experienced volunteers and trained WDFW staff support.
Incubation and rearing facilities are sited in areas that are not prone to flooding.	M	Expect to site project at site with low risk of flooding.

Hazard II: Ecological Effects

Criteria	Probability	Notes
Propagated summer chum are released at a life stage (1 gram fed fry) and time (March-April) that will reduce the risk of predation and competition effects on wild fish.	H	Will be key design element..
Summer chum are reared to release size on ground or surface water within the watershed targeted for supplementation or reintroduction.	H	Water source would be within watershed.
Fish health practices developed by the co-managers are applied in all hatchery activities to minimize the risk of fish disease occurrence, transmittal, and catastrophic loss.	H	Expected WDFW staff support would ensure proper procedures and treatment.

Hazard III: Reduction in Effective Population Size

Criteria	Probability	Notes
Hatchery fish are marked to accurately estimate proportion of hatchery fish spawning naturally in target population and proportion of wild fish spawning in hatchery.	H	Expected to be key element to plan for operations.
Natural spawning is regularly monitored to accurately estimate the proportion of hatchery fish spawning in target population.	M	Expected to be key element to plan for operations.
In the target population, the proportion of natural spawners that are hatchery fish is approximately equal to the proportion of wild fish that were taken into the hatchery the previous generation **OR** In the target population, the proportion of natural spawners that are hatchery-origin fish is larger than the proportion of wild fish that were taken into the hatchery the previous generation **AND** the wild population is increasing in abundance at a rate at least equal to the proportion of naturally spawning hatchery-origin fish	M	Broodstock undetermined but key project design element will be to find appropriate broodstock. Alternatives to be considered would likely be sufficiently removed from Dewatto River that any adults returning from project to donor population would be few or none.

Hazard III: Reduction in Effective Population Size (cont.)

OR The target wild population is believed to be in substantial danger of extinction within the next 35 years **AND** the effective number of breeders in the hatchery is as large as possible given the available broodstock. **OR** **The project is to reintroduce fish to a location removed from the target population with likelihood of less than 5-15% return to target population**.		

Hazard IV: Loss of Within Population Diversity

Source: Broodstock selection		
Criteria	Probability	Notes
Broodstock source is not already substantially domesticated.	H	Broodstock undetermined but unlikely to be domesticated.

Source: Broodstock collection		
Distributions of morphological, behavioral or life-history traits (e.g. run or spawn timing, size, appearance, age structure, etc) will be collected for target population.	H	Expect trained staff will record pertinent biological data.
Multi-trait distribution of broodstock sample closely matches the multi-trait distribution of target population (e.g. similar run and spawn timing, size, appearance, age structure, etc).	M	Broodstock collection parameters unknown but key element will be to obtain close match to target population.
Collection is technically and logistically possible (e.g. site is accessible throughout run, weirs have reasonable chance of continuous operation throughout season, necessary staff are available to carry out collection, funding is available to measure traits, etc).	M	Unknown but will be key element of project.
The effective population size will be maintained by collecting a minimum of 50 pairs except where the total population is less than 100 fish.	M	Criterion will be incorporated in plan.

Source: Mating, rearing and release methods (degree of difference between wild and hatchery environments and duration)		
The minimum standard for matings will be one male per female.	M	One to one or factorial matings will be a project objective.
Mating and rearing methods are similar enough to those observed in the wild to avoid substantial domestication selection pressure **OR** Hatchery program will be of short duration (3 generations equal to 12 years) **OR** The proportion of natural spawners that are hatchery-origin fish in the target population is less than 5-15%.	H	Project will be of short duration - not to exceed 12 years.

Source: Mating, rearing and release methods (degree of difference between wild and hatchery environments and duration) (cont.)		
Hatchery progeny will be released at essentially the same sizes and life-history stages as observed in the target population at the time of release **OR** Hatchery program will be of short duration (3 generations) **OR** The proportion of natural spawners that are hatchery-origin fish in the target population is less than 5-15%.	H	Hatchery progeny to reared to 1 gram size before release; however, program will be of short duration.

Source: Hatchery-induced genetic swamping (Ryman-Laikre effect)		
Broodstocking does not collect a small fraction of the spawner population and, through use of hatchery operation, generate a subsequent large proportion of the natural spawning population.	M	Broodstocking limitations undetermined but key element of project will be to avoid this effect.

Hazard V: Loss of Among Population Diversity

Source of hazard: Broodstock selection		
Criteria	Probability	Notes
All the discrete populations within the watershed containing the target population have been correctly identified.	H	Unknown broodstock source but expect to meet criterion.
Selected broodstock source is substantially genetically similar to target population.	H	Broodstock source will be target population.
Broodstock used for direct reintroduction is used only for one site.	H	General requirement for all projects.

Source: Broodstock collection		
Criteria	Probability	Notes
It will be possible to collect at a location and time such that only the target population will be collected.	H	Broodstock undetermined at this time but expect to meet criterion.

Source: Straying		
Criteria	Probability	Notes
Hatchery fish will be reared to release size in the watershed targeted for supplementation or reintroduction.	H	Location of facilities in watershed will be key element of project.
Hatchery fish will be marked to provide effective estimation of straying.	H	Fish will be marked to differentiate hatchery-origin and natural-origin spawners within watershed.
Adjacent spawning populations will be effectively monitored to detect straying.	L	Undetermined at this time.

Hazard VI: Masking of Population Status

Criteria	Probability	Notes
A sufficient proportion of hatchery fish are marked to estimate hatchery/wild ratios on the spawning grounds.	H	Expect to provide for adequate marking.
Sufficient wild spawning areas are surveyed to estimate hatchery/wild ratios accurately.	M	Expect would be key element to plan for operations.
Proportion of hatchery fish on spawning grounds is (or will be) less than 5-15% **OR** Hatchery program will be of short duration (3 generations equal to 12 years) **OR** Returning hatchery fish will spawn primarily in habitat currently underutilized by natural spawners of the same species.	H	Returning hatchery-origin fish will spawn in habitat currently not utilized and project is of short duration.

Skokomish Project

Hazard I: Hatchery Failure

Criteria	Probability	Notes
Hatchery personnel live on-site to allow rapid response to water source or power failures.	M	On-site living is possibility if existing hatchery facilities are used.
Low pressure/low water alarms functioning for water supplies serving summer chum incubation and rearing areas.	M	Alarm system exists if hatchery facilities in watershed are used.
All hatchery personnel responsible for rearing fish trained in standard fish propagation and fish health methods.	H	Expect experienced volunteers and trained WDFW staff support.
Incubation and rearing facilities are sited in areas that are not prone to flooding.	M	Undetermined but expect to site project with low risk of flooding.

Hazard II: Ecological Effects

Criteria	Probability	Notes
Propagated summer chum are released at a life stage (1 gram fed fry) and time (March-April) that will reduce the risk of predation and competition effects on wild fish.	H	Would be key design element.
Summer chum are reared to release size on ground or surface water within the watershed targeted for supplementation or reintroduction.	H	Water source would be within watershed.
Fish health practices developed by the co-managers are applied in all hatchery activities to minimize the risk of fish disease occurrence, transmittal, and catastrophic loss.	H	Expected WDFW staff support would ensure proper procedures and treatment.

Hazard III: Reduction in Effective Population Size

Criteria	Probability	Notes
Hatchery fish are marked to accurately estimate proportion of hatchery fish spawning naturally in target population and proportion of wild fish spawning in hatchery.	H	Expected to be key element of plan for operations.
Natural spawning is regularly monitored to accurately estimate the proportion of hatchery fish spawning in target population.	M	Expected to be key element of project operations.
In the target population, the proportion of natural spawners that are hatchery fish is approximately equal to the proportion of wild fish that were taken into the hatchery the previous generation **OR** In the target population, the proportion of natural spawners that are hatchery-origin fish is larger than the proportion of wild fish that were taken into the hatchery the previous generation **AND** the wild population is increasing in abundance at a rate at least equal to the proportion of naturally spawning hatchery-origin fish	M	Broodstock undetermined but key project design element will be to find appropriate broodstock. Alternatives to be considered would be sufficiently removed from Skokomish River that adult returns from project to donor population would be few to none.

Hazard III: Reduction in Effective Population Size

OR The target wild population is believed to be in substantial danger of extinction within the next 35 years **AND** the effective number of breeders in the hatchery is as large as possible given the available broodstock. **OR** **The project is to reintroduce fish to a location removed from the target population with likelihood of less than 5-15% return to target population.**		

Hazard IV: Loss of Within Population Diversity

Source: Broodstock selection		
Criteria	Probability	Notes
Broodstock source is not already substantially domesticated.	H	Broodstock undetermined but expect to meet criterion.

Source: Broodstock collection		
Distributions of morphological, behavioral or life-history traits (e.g. run or spawn timing, size, appearance, age structure, etc) will be collected for target population.	H	Expect trained staff will record pertinent biological data.
Multi-trait distribution of broodstock sample closely matches the multi-trait distribution of target population (e.g. similar run and spawn timing, size, appearance, age structure, etc).	M	Broodstock collection parameters unknown but key element will be to obtain close match to target population.
Collection is technically and logistically possible (e.g. site is accessible throughout run, weirs have reasonable chance of continuous operation throughout season, necessary staff are available to carry out collection, funding is available to measure traits, etc).	M	Unknown but will be key element of project.
The effective population size will be maintained by collecting a minimum of 50 pairs except where the total population is less than 100 fish.	M	Criterion will be incorporated in plan.

Source: Mating, rearing and release methods (degree of difference between wild and hatchery environments and duration)		
The minimum standard for matings will be one male per female.	M	One to one or factorial matings will be project objective.
Mating and rearing methods are similar enough to those observed in the wild to avoid substantial domestication selection pressure **OR** Hatchery program will be of short duration (3 generations equal to 12 years) **OR** The proportion of natural spawners that are hatchery-origin fish in the target population is less than 5-15%.	H	Project will be of short duration - not to exceed 12 years.

Source: Mating, rearing and release methods (degree of difference between wild and hatchery environments and duration) (cont.)		
Hatchery progeny will be released at essentially the same sizes and life-history stages as observed in the target population at the time of release **OR** Hatchery program will be of short duration (3 generations) **OR** The proportion of natural spawners that are hatchery-origin fish in the target population is less than 5-15%.	H	Hatchery progeny to be reared to 1 gram size before release; however, program will be of short duration.

Source: Hatchery-induced genetic swamping (Ryman-Laikre effect)		
Broodstocking does not collect a small fraction of the spawner population and, through use of hatchery operation, generate a subsequent large proportion of the natural spawning population.	M	Broodstocking limitations undetermined but key element of project will be to avoid this effect.

Hazard V: Loss of Among Population Diversity

Source of hazard: Broodstock selection		
Criteria	Probability	Notes
All the discrete populations within the watershed containing the target population have been correctly identified.	H	Unknown broodstock source but expect to meet criterion.
Selected broodstock source is substantially genetically similar to target population.	H	Broodstock source will be target population.
Broodstock used for direct reintroduction is used only for one site.	H	General requirement for all projects.

Source: Broodstock collection		
Criteria	Probability	Notes
It will be possible to collect at a location and time such that only the target population will be collected.	H	Broodstock undetermined at this time but expect to meet criterion.

Source: Straying		
Criteria	Probability	Notes
Hatchery fish will be reared to release size in the watershed targeted for supplementation or reintroduction.	H	Locating facilities in watershed will be key element of project.
Hatchery fish will be marked to provide effective estimation of straying.	H	Fish will be marked to differentiate hatchery-origin and natural-origin spawners within watershed.
Adjacent spawning populations will be effectively monitored to detect straying.	L	Undetermined at this time.

Hazard VI: Masking of Population Status

Criteria	Probability	Notes
A sufficient proportion of hatchery fish are marked to estimate hatchery/wild ratios on the spawning grounds.	H	Expect to provide for adequate marking.
Sufficient wild spawning areas are surveyed to estimate hatchery/wild ratios accurately.	M	Expect would be key element to plan for operations.
Proportion of hatchery fish on spawning grounds is (or will be) less than 5-15% **OR** Hatchery program will be of short duration (3 generations equal to 12 years) **OR** Returning hatchery fish will spawn primarily in habitat currently underutilized by natural spawners of the same species.	H	Returning hatchery fish will spawn in habitat currently underutilized and project will be of short duration.

Anderson Project

Hazard I: Hatchery Failure

Criteria	Probability	Notes
Hatchery personnel live on-site to allow rapid response to water source or power failures.	M	Site and personnel undetermined.
Low pressure/low water alarms functioning for water supplies serving summer chum incubation and rearing areas.	M	Specific project design not yet determined.
All hatchery personnel responsible for rearing fish trained in standard fish propagation and fish health methods.	H	Expect experienced volunteers and trained WDFW staff support.
Incubation and rearing facilities are sited in areas that are not prone to flooding.	M	Expect to site project at site with low risk of flooding.

Hazard II: Ecological Effects

Criteria	Probability	Notes
Propagated summer chum are released at a life stage (1 gram fed fry) and time (March-April) that will reduce the risk of predation and competition effects on wild fish.	H	Will be key design element.
Summer chum are reared to release size on ground or surface water within the watershed targeted for supplementation or reintroduction.	H	Water source would be within watershed.
Fish health practices developed by the co-managers are applied in all hatchery activities to minimize the risk of fish disease occurrence, transmittal, and catastrophic loss.	H	Expected WDFW staff support would ensure proper procedures and treatment.

Hazard III: Reduction in Effective Population Size

Criteria	Probability	Notes
Hatchery fish are marked to accurately estimate proportion of hatchery fish spawning naturally in target population and proportion of wild fish spawning in hatchery.	H	Expect to be key element to plan for operations.
Natural spawning is regularly monitored to accurately estimate the proportion of hatchery fish spawning in target population.	M	Expect to be key element to plan for operations.
In the target population, the proportion of natural spawners that are hatchery fish is approximately equal to the proportion of wild fish that were taken into the hatchery the previous generation **OR** In the target population, the proportion of natural spawners that are hatchery-origin fish is larger than the proportion of wild fish that were taken into the hatchery the previous generation **AND** the wild population is increasing in abundance at a rate at least equal to the proportion of naturally spawning hatchery-origin fish	M	Broodstock undetermined but key project design element will be to find appropriate broodstock. Alternatives to be considered would be sufficiently removed from Anderson Creek that expected adult returns from project to donor population would be few or none.

Hazard III: Reduction in Effective Population Size

OR The target wild population is believed to be in substantial danger of extinction within the next 35 years **AND** the effective number of breeders in the hatchery is as large as possible given the available broodstock. **OR** **The project is to reintroduce fish to a location removed from the target population with likelihood of less than 5-15% return to target population.**		

Hazard IV: Loss of Within Population Diversity

Source: Broodstock selection		
Criteria	Probability	Notes
Broodstock source is not already substantially domesticated.	H	Broodstock undetermined but unlikely to be domesticated.

Source: Broodstock collection		
Distributions of morphological, behavioral or life-history traits (e.g. run or spawn timing, size, appearance, age structure, etc) will be collected for target population.	H	Expect trained staff will record pertinent biological data.
Multi-trait distribution of broodstock sample closely matches the multi-trait distribution of target population (e.g. similar run and spawn timing, size, appearance, age structure, etc).	M	Broodstock collection parameters unknown but key element will be to obtain close match to target population.
Collection is technically and logistically possible (e.g. site is accessible throughout run, weirs have reasonable chance of continuous operation throughout season, necessary staff are available to carry out collection, funding is available to measure traits, etc).	M	Unknown but will be key element of project.
The effective population size will be maintained by collecting a minimum of 50 pairs except where the total population is less than 100 fish.	M	Criterion will be incorporated in plan.

Source: Mating, rearing and release methods (degree of difference between wild and hatchery environments and duration)		
The minimum standard for matings will be one male per female.	M	One to one or factorial matings will be a project objective.
Mating and rearing methods are similar enough to those observed in the wild to avoid substantial domestication selection pressure **OR** Hatchery program will be of short duration (3 generations equal to 12 years) **OR** The proportion of natural spawners that are hatchery-origin fish in the target population is less than 5-15%.	H	Project will be of short duration - not to exceed 12 years.

Source: Mating, rearing and release methods (degree of difference between wild and hatchery environments and duration) (cont.)		
Hatchery progeny will be released at essentially the same sizes and life-history stages as observed in the target population at the time of release **OR** Hatchery program will be of short duration (3 generations) **OR** The proportion of natural spawners that are hatchery-origin fish in the target population is less than 5-15%.	H	Hatchery progeny to reared to 1 gram size before release; however, program will be of short duration.

Source: Hatchery-induced genetic swamping (Ryman-Laikre effect)		
Broodstocking does not collect a small fraction of the spawner population and, through use of hatchery operation, generate a subsequent large proportion of the natural spawning population.	M	Broodstocking limitations undetermined but key element of project will be to avoid this effect.

Hazard V: Loss of Among Population Diversity

Source of hazard: Broodstock selection		
Criteria	Probability	Notes
All the discrete populations within the watershed containing the target population have been correctly identified.	H	Unknown broodstock source but expect to meet criterion.
Selected broodstock source is substantially genetically similar to target.	H	Broodstock source will be target population.
Broodstock used for direct reintroduction is used only for one site.	H	General requirement for all projects.

Source: Broodstock collection		
Criteria	Probability	Notes
It will be possible to collect at a location and time such that only the target population will be collected.	H	Broodstock undetermined at this time but expect to meet criterion.

Source: Straying		
Criteria	Probability	Notes
Hatchery fish will be reared to release size in the watershed targeted for supplementation or reintroduction.	H	Location of facilities in watershed will be key element of project.
Hatchery fish will be marked to provide effective estimation of straying.	H	Fish will be marked to differentiate hatchery-origin and natural-origin spawners within watershed.
Adjacent spawning populations will be effectively monitored to detect straying.	L	Undetermined at this time.

Hazard VI: Masking of Population Status

Criteria	Probability	Notes
A sufficient proportion of hatchery fish are marked to estimate hatchery/wild ratios on the spawning grounds.	H	Expect to provide for adequate marking.
Sufficient wild spawning areas are surveyed to estimate hatchery/wild ratios accurately.	M	Expect would be key element to plan for operations.
Proportion of hatchery fish on spawning grounds is (or will be) less than 5-15% **OR** Hatchery program will be of short duration (3 generations equal to 12 years) **OR** Returning hatchery fish will spawn primarily in habitat currently underutilized by natural spawners of the same species.	H	Returning hatchery-origin fish will spawn in habitat currently not utilized and project would be of short duration.

Finch Project

Hazard I: Hatchery Failure

Criteria	Probability	Notes
Hatchery personnel live on-site to allow rapid response to water source or power failures.	M	On-site living is possibility if existing hatchery facilities are used.
Low pressure/low water alarms functioning for water supplies serving summer chum incubation and rearing areas.	M	Alarm system exists if hatchery facilities in watershed are used.
All hatchery personnel responsible for rearing fish trained in standard fish propagation and fish health methods.	H	Expect experienced volunteers and trained WDFW staff support.
Incubation and rearing facilities are sited in areas that are not prone to flooding.	M	Expect to site project at site with low risk of flooding.

Hazard II: Ecological Effects

Criteria	Probability	Notes
Propagated summer chum are released at a life stage (1 gram fed fry) and time (March-April) that will reduce the risk of predation and competition effects on wild fish.	H	Will be key design element.
Summer chum are reared to release size on ground or surface water within the watershed targeted for supplementation or reintroduction.	H	Water source would be within watershed.
Fish health practices developed by the co-managers are applied in all hatchery activities to minimize the risk of fish disease occurrence, transmittal, and catastrophic loss.	H	Expected WDFW staff support would ensure proper procedures and treatment.

Hazard III: Reduction in Effective Population Size

Criteria	Probability	Notes
Hatchery fish are marked to accurately estimate proportion of hatchery fish spawning naturally in target population and proportion of wild fish spawning in hatchery.	H	Expect to be key element to plan for operations.
Natural spawning is regularly monitored to accurately estimate the proportion of hatchery fish spawning in target population.	H	Presence of hatchery rack facilitates monitoring.
In the target population, the proportion of natural spawners that are hatchery fish is approximately equal to the proportion of wild fish that were taken into the hatchery the previous generation, **OR** In the target population, the proportion of natural spawners that are hatchery-origin fish is larger than the proportion of wild fish that were taken into the hatchery the previous generation **AND** the wild population is increasing in abundance at a rate at least equal to the proportion of naturally spawning hatchery-origin fish,	M	Broodstock undetermined but key project design element will be to find appropriate broodstock. Alternatives to be considered would be sufficiently removed from Finch Creek that expected adult returns from project to donor population would be few or none.

Hazard III: Reduction in Effective Population Size

OR The target wild population is believed to be in substantial danger of extinction within the next 35 years **AND** the effective number of breeders in the hatchery is as large as possible given the available broodstock, **OR** **The project is to reintroduce fish to a location removed from the target population with likelihood of less than 5-15% return to target population.**		

Hazard IV: Loss of Within Population Diversity

Source: Broodstock selection		
Criteria	Probability	Notes
Broodstock source is not already substantially domesticated.	H	Broodstock undetermined but unlikely to be domesticated.

Source: Broodstock collection		
Distributions of morphological, behavioral or life-history traits (e.g. run or spawn timing, size, appearance, age structure, etc) will be collected for target population.	H	Expect trained staff will record pertinent biological data.
Multi-trait distribution of broodstock sample closely matches the multi-trait distribution of target population (e.g. similar run and spawn timing, size, appearance, age structure, etc).	M	Broodstock collection parameters unknown but key element will be to obtain close match to target population.
Collection is technically and logistically possible (e.g. site is accessible throughout run, weirs have reasonable chance of continuous operation throughout season, necessary staff are available to carry out collection, funding is available to measure traits, etc).	M	Unknown but will be key element of project.
The effective population size will be maintained by collecting a minimum of 50 pairs except where the total population is less than 100 fish.	M	Criterion will be incorporated in plan.

Source: Mating, rearing and release methods (degree of difference between wild and hatchery environments and duration)		
The minimum standard for matings will be one male per female.	M	One to one or factorial matings will be a project objective.
Mating and rearing methods are similar enough to those observed in the wild to avoid substantial domestication selection pressure **OR** Hatchery program will be of short duration (3 generations equal to 12 years) **OR** The proportion of natural spawners that are hatchery-origin fish in the target population is less than 5-15%.	H	Project will be of short duration - not to exceed 12 years.

Source: Mating, rearing and release methods (degree of difference between wild and hatchery environments and duration) (cont.)		
Hatchery progeny will be released at essentially the same sizes and life-history stages as observed in the target population at the time of release **OR** Hatchery program will be of short duration (3 generations) **OR** The proportion of natural spawners that are hatchery-origin fish in the target population is less than 5-15%.	H	Hatchery progeny to reared to 1 gram size before release; however, program will be of short duration.

Source: Hatchery-induced genetic swamping (Ryman-Laikre effect)		
Broodstocking does not collect a small fraction of the spawner population and, through use of hatchery operation, generate a subsequent large proportion of the natural spawning population.	M	Broodstocking limitations undetermined but key element of project will be to avoid this effect.

Hazard V: Loss of Among Population Diversity

Source of hazard: Broodstock selection		
Criteria	Probability	Notes
All the discrete populations within the watershed containing the target population have been correctly identified.	H	Unknown broodstock source but expect to meet criterion.
Selected broodstock source is substantially genetically similar to target.	H	Broodstock source will be target population.
Broodstock used for direct reintroduction is used only for one site.	H	General requirement for all projects.

Source: Broodstock collection		
Criteria	Probability	Notes
It will be possible to collect at a location and time such that only the target population will be collected.	H	Broodstock undetermined at this time but expect to meet criterion.

Source: Straying		
Criteria	Probability	Notes
Hatchery fish will be reared to release size in the watershed targeted for supplementation or reintroduction.	H	Location of facilities in watershed will be key element of project.
Hatchery fish will be marked to provide effective estimation of straying.	H	Fish will be marked to differentiate hatchery-origin and natural-origin spawners within watershed.
Adjacent spawning populations will be effectively monitored to detect straying.	L	Undetermined at this time.

Hazard VI: Masking of Population Status

Criteria	Probability	Notes
A sufficient proportion of hatchery fish are marked to estimate hatchery/wild ratios on the spawning grounds.	H	Expect to provide for adequate marking.
Sufficient wild spawning areas are surveyed to estimate hatchery/wild ratios accurately.	H	Presence of hatchery rack facilitates monitoring.
Proportion of hatchery fish on spawning grounds is (or will be) less than 5-15% **OR** Hatchery program will be of short duration (3 generations equal to 12 years) **OR** Returning hatchery fish will spawn primarily in habitat currently underutilized by natural spawners of the same species.	H	Returning hatchery-origin fish will spawn in habitat currently not utilized and project would be of short duration.

Appendix Report 3.5
Estuarine Landscape Impacts on Hood Canal and Strait of Juan de Fuca Summer Chum Salmon and Recommended Actions

by
Charles A. Simenstad[1]

Introduction

Summer chum salmon rely on natural features and processes of estuarine and nearshore habitats during their juvenile rearing in subestuary[2] deltas and migration through Hood Canal and the eastern Strait of Juan de Fuca (Appendix Figure 3.5.1). Watershed and summer chum population factors that influence timing and condition of fry emigration to deltas are often disconnected from carrying capacity conditions affecting productivity and carrying capacity within the deltas. These within-delta factors are in turn often independent of factors over the broader migratory route of summer chum during their vulnerable transition to the North Pacific Ocean. However, research on the estuarine ecology of juvenile salmon has typically focused on subestuarine delta, and particularly emergent wetland, habitats but much less on salmonid use of nearshore marine habitats that interconnect deltas in estuarine inland sea systems such as Hood Canal, Puget Sound and the Strait of Juan de Fuca. By bridging the widely dispersed deltas, natural nearshore "landscape linkages" of natural beaches, eelgrass beds and unimpacted drift cells provide productive, protected migratory corridors for summer chum to span delta rearing areas and effectively transition to open-water migration (Appendix Figure 3.5.2). Cumulative impacts on the integrity of these nearshore corridors threaten not only the function of the corridors but also the opportunity to exploit the intervening delta habitats. This report addresses the need for a broader, landscape perspective and assessment of the role of these nearshore corridors in the early estuarine-marine life history of summer chum. In justifying this argument, I describe: 1) the regional and watershed setting, 2) pertinent genetic and life history characteristics of summer chum, 3) estuarine landscape structure and how anthropogenic changes have altered its function, 4) a conceptual model of summer chum rearing and migration, 5) important aspects of the response by summer chum to landscape structure and these changes, and 6) research and management gaps required to incorporate estuarine landscape structure into recovery efforts for summer chum.

As with almost all other fisheries science approaches to anadromous fishes, accounting for factors that have likely led to the decline of summer chum salmon, as well as considerations of recovery

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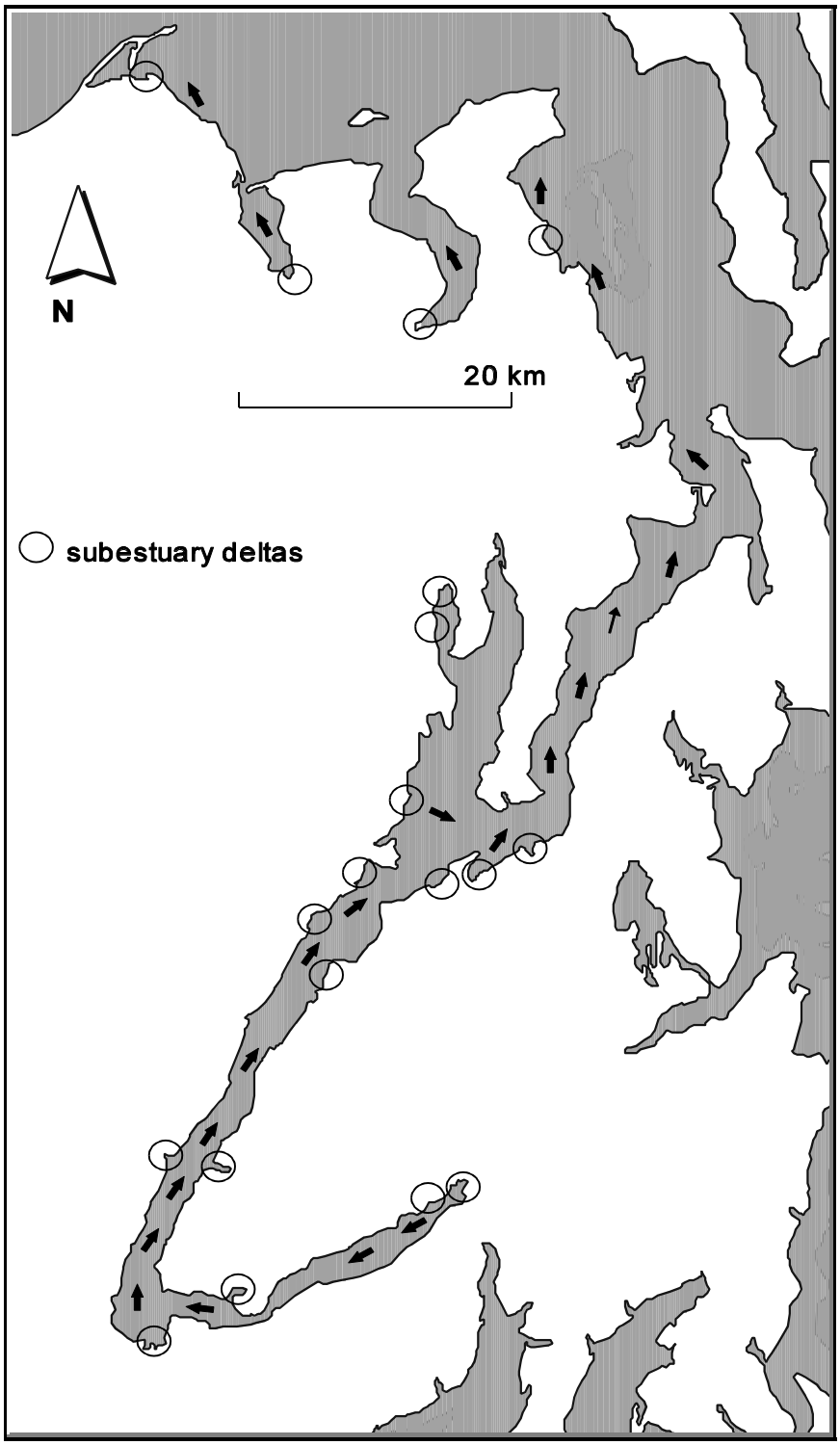
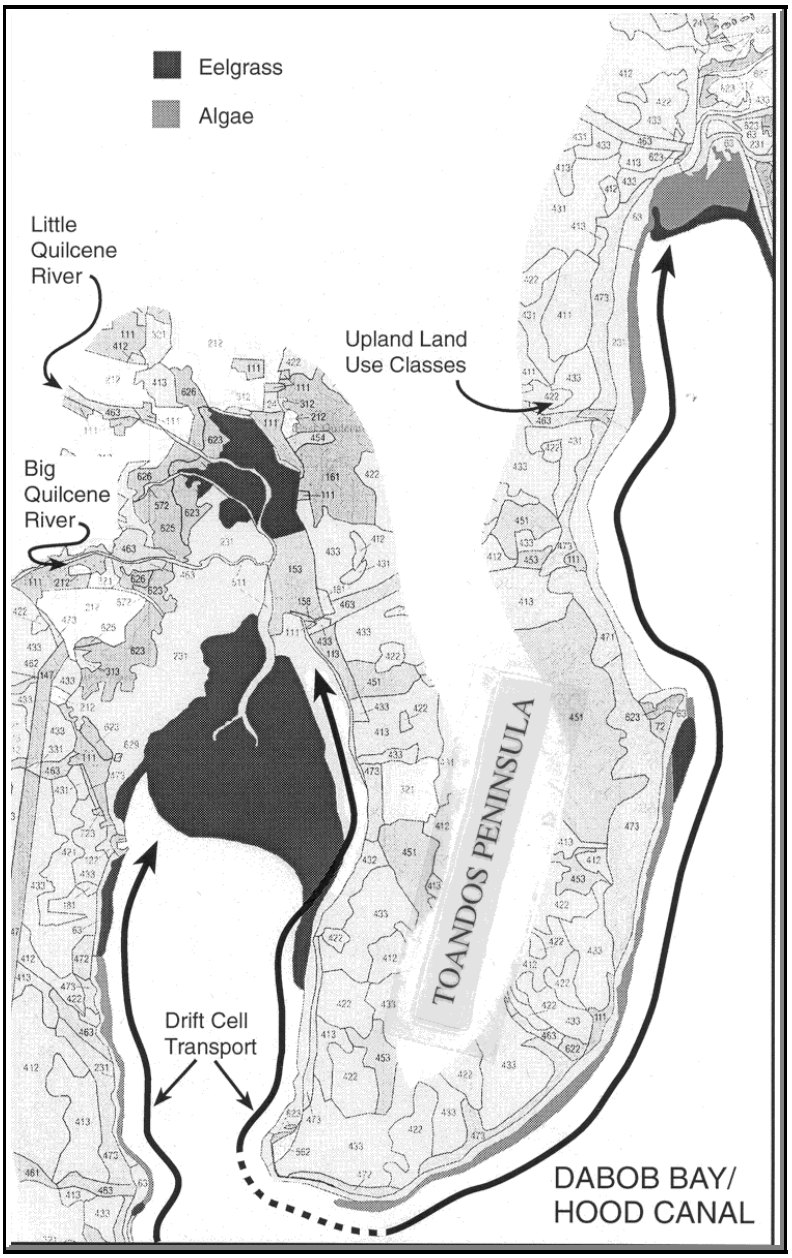
[2] The term *subestuary* is herein used to define estuarine deltas at the termini of watersheds, while the receiving body of water, perhaps more appropriately termed an *inland sea*, is still technically an estuary because, although it encloses a number of subestuaries, freshwater is measurably diluted by seawater.

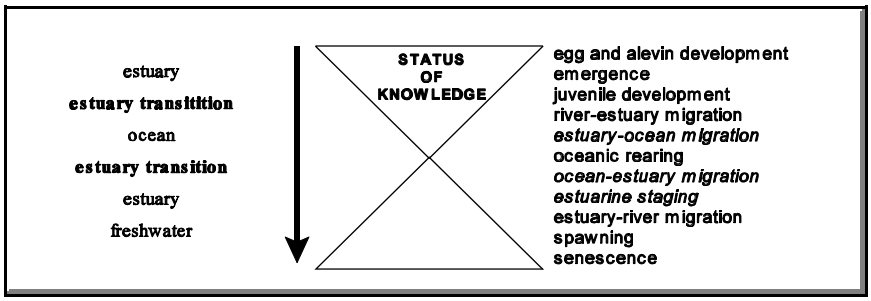


Appendix Figure 3.5.1. Nearshore movement (black arrows) of juvenile summer chum among subestuary deltas (circles) in Hood Canal and eastern Strait of Juan de Fuca that are important estuarine rearing habitats and migratory corridors. Primary corridors for fry early after their entry into Hood Canal are focused tightly along the shoreline, but as the fish grow larger they appear more frequently in open water and will cross the Canal (as indicated by some arrows in the middle of the Canal).



Appendix Figure 3.5.2. Segment of Jefferson County (upper Dabob Bay) of Washington Coastal Zone Atlas showing delta and shoreline migratory habitats of juvenile summer chum; Big and Little Quilcene rivers delta occupy left center of image, while portion of Tarboo Creek estuary is in upper right. This original Atlas map has been enhanced to illustrate eelgrass (dark gray-black) and algae (stippled light gray) habitats and direction of along-shore drift (arrows). Note contrast between broad expanses of eelgrass and algae habitats on estuarine deltas with the narrow, confined migratory corridors along shorelines that are often interrupted. Indicated nearshore drift is from Johannessen (1992).

initiatives, has traditionally conformed to an "hourglass" distribution relative to their life history (Appendix Figure 3.5.3). That is, the basis of knowledge and attribution of importance to the survival and resilience of summer chum has predominantly centered on freshwater phases of their life history and diminished with transition to and from their oceanic phase. This is particularly the case for the "estuary transition" phases where juvenile chum salmon are still confined to shallow water habitats but for a variety of behavioral and ecological mandates are migrating beyond the subestuary directly associated with their watershed of origin. Next to chinook salmon, juvenile chum salmon have been described as the species most dependent on



Appendix Figure 3.5.3 Status of knowledge about salmon ecology as a function of life history stanzas.

estuaries (Healey 1982; Levy and Northcote 1982; Simenstad et al. 1982; Salo 1991). This "dependence" is inferred from extended residence time (average individual residence time ~25 days; Simenstad et al. 1982) that is assumed to result in rapid growth and larger size at emigration from the estuary in an environment of comparatively lower predation rate.

A multitude of factors, including size and physiological condition upon entry, available prey, surface outflow, shoreline habitat structure, refugia from predators, can potentially influence residence time in an estuary like Hood Canal because the rate of migration is influenced heavily by the carrying capacity of the estuarine environment and the ecophysiological state of the fish. Most research that provides insight into these factors originates from distinct subestuaries at the termini of major rivers and watersheds that have large chum salmon populations. Other than the earlier investigations of juvenile chum salmon distribution in the Strait of Georgia (e.g., Robinson 1969) and Hood Canal (e.g., Salo et al. 1980, Wissmar and Simentad 1988), there has been very little research on the larger scale of juvenile chum salmon ecology, as they migrate among subestuaries along the "estuarine landscape" before entering the North Pacific Ocean.

Regional Watershed and Estuarine Structure

As for many anadromous fishes, salmon have developed diffuse population and life history traits that indicate strong natural selection in response to variation in aquatic, estuarine and ocean environments. Life history traits can reflect both watershed-subestuary variation as well as whole-system variability. Summer chum of the Hood Canal and eastern Strait of Juan de Fuca region have evolved in a complex landscape and estuarine setting, with strong regional variation in land form, riverine inflow, and estuarine circulation and habitat structure. Furthermore, human modifications to these regional characteristics have introduced both cumulative and far-reaching impacts to the estuary. To effectively assess the decline of summer chum

salmon populations, as well as their recovery, the larger estuarine landscape scale as well as the watershed-estuary scale must be considered.

Hood Canal straddles a sharp break in landform, between the Olympic Mountains to the west and the Willamette-Puget Lowland to the east, with it's watersheds positioned on quaternary and Tertiary volcanic rocks or Upper and Lower Tertiary sedimentary rocks, and strongly divided between ultisol (haplohumult) soils on the west and inceticol (haplumbrept, with some cryumbrept) soils on the east (Jackson and Kimerling 1993). The Olympic Mountains produce a strong influence on seasonal precipitation and riverflow on the western region, with up to 2.5 m mean annual runoff within the watersheds draining into the western side of Hood Canal, 1.5-2.0 m on the southern edge of the Olympics, ~1 m on the lowlands draining into the eastern side, and <0.5 m in the "rain shadow" of some regions of the eastern Strait of Juan de Fuca. As a result, rivers draining into Hood Canal from the eastern Olympics have average flows of between 10 (e.g., Hamma Hamma) and 43 m^3s^{-1} (e.g., Elwha), but with peak flows as high as 250 (Duckabush) to 760 m^3s^{-1} (Skokomish). In contrast, streams on the eastern side draining the Kitsap Peninsula have very low flows (e.g., < 0.01 m^3s^{-1}) especially in late summer and early fall. Land use in the watershed is heavily oriented toward forest harvest, with some pasture and very little cropland.

Hood Canal is a fjord type of estuary: long (100 km), narrow (0.8-6.4 km; avg. 2.4 km) and deep (avg. >150 m) with glacial sills that restrict circulation. Because of this structure, except under strong wind forcing, the water column of the Canal is usually highly stratified, with a shallow lens of fresh to brackish water at the surface overlaying waters of near-ocean salinity. Due to the sills, water exchange and turnover are limited and residence time long, especially in the southern reaches of the Canal and Dabob Bay, and cold, nutrient-rich upwelling water from the North Pacific intrudes only in late summer (Friebertshauser et al. 1971; Yoshinaka and Ellifrit 1974; Strickland 1983).

The Strait of Juan de Fuca (shared to a lesser degree with the Strait of Georgia) is the primary point of exchange between oceanic and Puget Sound waters and the migration route of most juvenile summer chum from Hood Canal to the North Pacific Ocean. The deep, fjord structure of the eastern Strait was excavated by the advancement and retreat of the Strait of Juan de Fuca lobe of the Cordilleran Ice Sheet (Burns 1985). It's gently sloping U-shaped cross-channel profile is 18 km wide at it's narrowest point (Race Rocks-Angeles Pt.) and its depth is >150 m except over the shallow (55 m) glacial sill that spans the eastern end south from Victoria, B.C. (Thomson 1981). Unlike the strong salinity stratification in Hood Canal, salinity distribution in the Strait is more of an estuarine "salt wedge" but salinities are still >31 ppt except in the spring when freshwater outflow from Puget Sound and the Fraser River drop surface waters to 28-30 ppt. Due to the stronger wind, wave and current regimes in the eastern Strait (Downing 1983), shoreline habitats are much more dynamic and dominated by steeper, coarser sediments than in Hood Canal. However, Discovery, Sequim and Dungeness bays that are the termini of watersheds supporting summer chum tend to be more protected and are characterized by beach environments similar to Hood Canal.

Genetic and Life History Characteristics of Summer Chum Populations

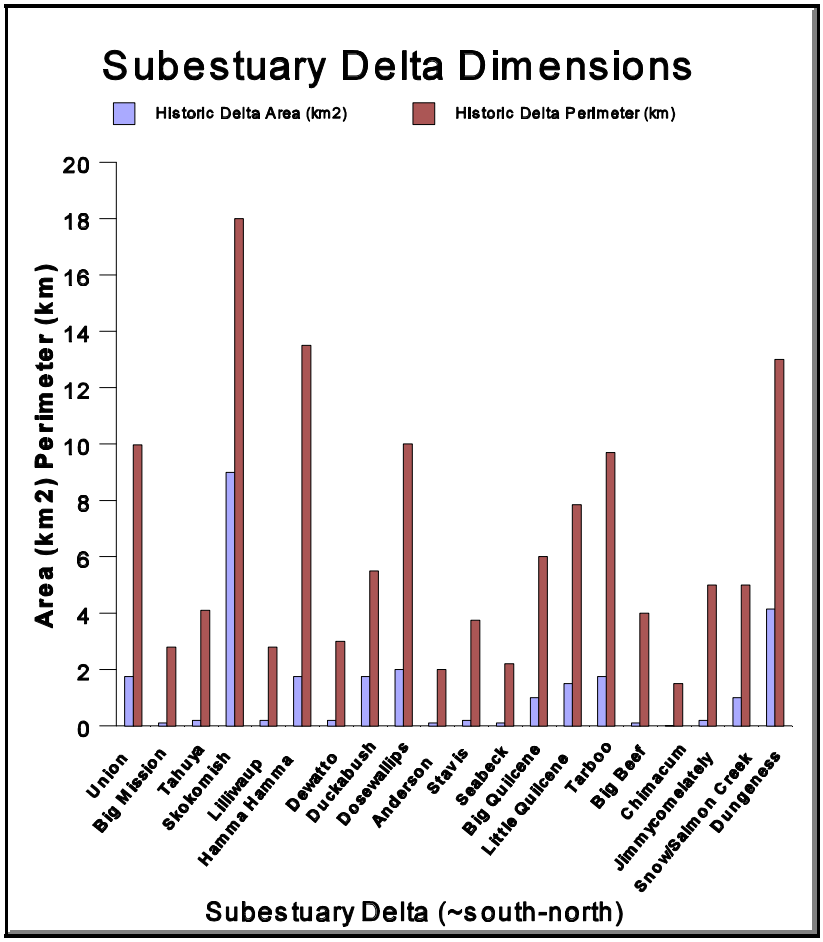
Summer chum have evolved into discrete metapopulations that reflect their estuarine rearing, as well as their watershed spawning and incubating, setting within each watershed. Likely reflecting the regional physiography over which they reproduce and rear, summer chum salmon from Hood Canal and the eastern Strait of Juan de Fuca are genetically isolated from other chum salmon populations in the region (Johnson et al. 1997). In fact, the genetic structure (based on 34 loci) of the nine summer chum stocks analyzed by Johnson et al. (1997) were entirely displaced from other chum stocks (including four southern Puget Sound summer chum) on the basis of multidimensional scaling in two dimensions of chord genetic differences. Within the Hood Canal-eastern Strait of Juan de Fuca region, visible separation (based on graphical interpretation) was also evident for populations of 1) the five eastern Olympic Mountains watersheds from those of 2) a southern Canal (Union) river, and 3) three eastern Strait of Juan de Fuca rivers. Internal variation was apparently high even within these groupings, as indicated by the separation among the three eastern Strait of Juan de Fuca rivers. Earlier (Wright 1978, cited in WDFW and WWTIT 1994) classification of Hood Canal summer chum stocks based on genetic distance indicated strongest affinities among the Union River and other Hood Canal stocks but more distinct separation from the Jimmycomelately Creek (Sequim Bay) and Salmon and Snow creeks (Discovery Bay) stocks.

While there is little comprehensive documentation of life history characteristics among Hood Canal and eastern Strait of Juan de Fuca summer chum populations, comparison of river entry and spawning timing for several rivers groupings also indicates comparable variation that may correspond to regional physiography and genetic distinction. The window of river entry for the Union River (early August past mid-September) is earlier than at other Hood Canal and eastern Strait of Juan de Fuca (Discovery Bay) streams (early September past mid-October) (Johnson et al. 1997). Spawning may be even more distinct: late August to early October in the Union River (greater delay between river entry and spawning); early September past mid-October in the eastern Strait of Juan de Fuca (short to no delay); and, mid-September to late October in other Hood Canal rivers (shorter delay than Union River). This suggests that, if the Union River is representative, juveniles from the southern Hood Canal populations will be entering the Canal earlier than the central and northern Hood Canal fish, particularly if river temperatures in the Olympic Mountains watersheds are significantly lower than the Puget Lowland rivers, promoting more rapid egg and alevin development. Thus, there are genetic traits to physiographically separated populations that have significant implications to estuarine utilization by summer chum.

Estuarine Landscape Structure

The fjord estuary structure of Hood Canal, Puget Sound and the Strait of Juan de Fuca is particularly important to the linkage of watersheds and subestuary deltas supporting summer chum as they emigrate from freshwater and migrate seaward. Because juvenile salmon tend to migrate in surface waters, and in particularly shallow water as fry early in their estuarine life history, they are somewhat confined to migratory corridors between these subestuary patches that are distributed along the shoreline adjacent to the deeper, open waters of the Canal, Admiralty Inlet and the eastern Strait of Juan de Fuca (see Conceptual Model

section, below). Thus, while the broad expanses of intertidal delta habitats (emergent marsh, mudflat, eelgrass, dendritic channels) at the subestuary termini of the major watersheds comprise expansive rearing habitats (Appendix Figure 3.5.2; but see individual subestuary accounts that describe proportional and qualitative loss of habitat), these deltas are relatively dispersed "patches" along the deep channel "matrix" of the fjord axis (Appendix Figure 3.5.1). Eleven of the twenty deltas (55%) are less than 1 km^2 in area, and only two are >2 km^2. The largest deltas (Skokomish, Dosewallips, Dabob Bay deltas, Dungeness) are widely separated along the >150 km distribution of summer chum systems. Thus, the estuarine rearing capacity for summer chum fry early in their seaward migration is a function of the interlinked *system* of subestuary deltas and shallow nearshore corridors.



Appendix Figure 3.5.4. Estimated historic dimensions of subestuary deltas within documented summer chum distribution; see earlier subestuary descriptions for methodology in estimating historic delta areas.

The resulting summer chum salmon migratory corridors between subestuary deltas tend to be composed of a relatively higher energy, narrow intertidal-shallow subtidal beaches of moderate gradient and usually comprised of mixed cobble, gravel and coarse sand (Appendix Figure 3.5.4). Natural beach erosion and

shoreline drift maintain these beach processes that continuously supply, transport and deposit sediments along discrete beach "drift cells" or "drift sectors."[3] Important zones within drift cells are the areas of sediment origin or 'source zones,' the 'transport zone' of prominent longshore drift, and the termini or 'sink zones' where drift cells end by either sediment accretion or by transport into deeper water (Canning and Shipman 1994).

Perhaps one of the most important habitats for summer chums salmon within this zone is a typically dense band of the native eelgrass, *Zostera marina*. Eelgrass provides a vast array of direct (i.e., "habitat") functions in support of estuarine biota but may be equally as important as one of the, if not *the*, major sources of organic matter to intertidal/shallow subtidal food webs in Hood Canal (Simenstad and Wissmar 1985). Eelgrass is somewhat constrained to a longitudinal patch concentrated in tidal elevations between +1 m (in areas of low elevation gradient) to -2 m (but may occur as deep as -6.6 m in extremely clear waters; Phillips 1984) relative to MLLW. This eelgrass corridor is often (in the absence of shoreline development) contiguous within a drift cell but also occurs in fragmented patches between drift cells, depending upon the nature of the shoreline at convergence of drift cells.

Thus, the steeper the beach gradient and more turbid the waters, the narrower the eelgrass corridor. Eelgrass recruits to and persists optimally in mud or muddy-sand to sandy-gravel substrates (Phillips 1984) and can be inhibited by shifts to coarser substrates (e.g., gravel, cobble) and by shading, including by overwater structures such as docks (see Simenstad et al. 1998). Other prominent habitats that are integrated with the eelgrass corridor are macroalgae and kelps and mud- and sandflats. From a variety of ecological standpoints, the functions of this beach landscape for migrating juvenile summer chum should be viewed as the *net* effect of the arrangement of habitat patches, rather than the independent effect of any one habitat.

There are two other scales of this landscape that should also be considered beyond drift cell segments. The next step in the hierarchy of scale is the "nearshore reach" between subestuary deltas that are often composed of multiple drift cell segments. The number of segments would often dictate the extent of eelgrass corridor connectivity between subestuary delta rearing areas for summer chum. The other scale of importance involves the larger physiographic areas of embayments and 'clusters' of deltas (Appendix Figure 3.5.1). In this respect, the location and position of the southern "Big Bend," Dabob Bay, Discovery and Sequim bays will also play a role in terms of summer chum interaction with the estuarine landscape, depending upon the origin of migrating fry.

[3] Drift cells have been mapped for the Hood Canal region, covering Kitsap and Jefferson counties, by Schwartz et al. (1991) and Johannessen (1992). It is beyond the scope of this report to describe drift cell structure and processes in detail.

Human Alterations of Estuarine Landscape Structure Likely Impacting Juvenile Summer Chum

Human alterations of the subestuary deltas have been described earlier. While some of the same human alterations to these deltas (e.g., filling, excavation, and jetties) also occur along the nearshore corridors, a number of modifications impose particular impacts to these beach habitats. Acute impacts, involving relatively permanent loss of habitat by filling or excavation that are common in some of the Hood Canal subestuary deltas are not necessarily as prevalent in the intervening shorelines between these deltas. However, shoreline development has caused some direct and considerable indirect impacts in these reaches. Among those documented to cause impacts are intertidal fills, installation of bulkheads and docks and destruction of shoreline vegetation. Bulkheads that intrude into the intertidal zone increase the rate of beach erosion by intensifying the wave energy regime, causing the coarsening of sediments (Macdonald et al. 1994; Canning and Shipman 1995). Bulkheads and other beach armoring or "hardening" also inhibit or eliminate sources of beach sediment material in the source regions of drift cells. Both of these factors decrease the amount and maintenance of fine-sediment structure to shorelines, which can ultimately alter habitat structure from eelgrass and other mixed-fine substrate communities to more coarse substrate communities with less habitat value for migrating salmon fry (Thom and Shreffler 1994). The consequence is either fragmentation or loss of eelgrass as a viable migratory corridor and degradation of habitat for prey and salmon foraging. Low (intertidal) elevation bulkheads, other types of fills, and docks can force fry from shallow water into deeper water, where risk to predation may be significantly higher. Shading and the physical structure from docks also eliminates eelgrass and/or prevents its recruitment. Removal of shoreline vegetation reduces shade and import of large woody debris (LWD), which impacts the supply of terrestrial insects (that salmon also feed on), epibenthic prey resources, and the spawning habitat of baitfish which are prey resources of larger juvenile and resident salmon.

Other potential impacts that are suspected but have not been thoroughly evaluated include boat activity, leakage of septic tanks, and some aquaculture and shellfish harvesting methods. Associated boat activity can result in propeller scouring of benthic communities and potentially remove whole segments of eelgrass patches. Leaking septic tanks could enter beach habitats and cause nutrient enrichment along beach groundwater seepage zones, and concordant response by macroalgae if excessive could cause localized areas of intense organic decomposition and sediment anoxia. Some shellfish aquaculture practices, such as diking and mechanical harvesting can be deleterious to eelgrass under some conditions, but the scale (size, intensity or frequency) of disturbance must be of significant threshold to cause impact. For instance, the impact of beach graveling and predator exclusion netting for clam enhancement on juvenile salmon prey resources depends upon the scale of application (Simenstad and Fresh 1995). Harvesting of natural shellfish populations may also impose some isolated, small-scale impacts, as in hydraulic harvesting of geoduck (*Panope generosa*) clams in intertidal and shallow subtidal habitats, including eelgrass beds despite the fact that that practice is against WDFW/DNR and tribal policy and regulations.

While the imprint of any one of these impacts is small compared to the 10s to 100s of acres of diked emergent marshes in subestuary deltas, the cumulative effect can be exceedingly destructive of summer chum habitat along the fry's migratory corridor. Fragmentation of eelgrass may be one of the more insidious

impacts because of the multifunctional role of eelgrass in providing a migratory corridor with both abundant prey resources and a continuous "strip" patch that offers refuge from predation. Although this has not been examined scientifically, loss and disruption of the eelgrass corridor infers reduced prey resources, diminished carrying capacity under some circumstances, migration delays and increased predation risk.

Conceptual Model of Estuarine Rearing and Migration of Juvenile Chum Salmon

The relationship of summer chum salmon to the structure of Hood Canal and eastern Strait of Juan de Fuca can best be defined within the context of a simple conceptual model that describes our current level of understanding, albeit limited, about the factors affecting their response to estuarine conditions. This remains a conceptual model, rather than a more deterministic or predictive model, because most of the functional relationships between juvenile salmon response to estuarine factors remain unquantified.

In addition to the body of literature that presently encapsulates our understanding of the estuarine life history and ecology of juvenile salmon in Pacific Northwest estuaries (e.g., Healey 1982; Levy and Northcote 1982; Simenstad et al. 1982; Salo 1991; see also Johnson et al. 1997 for a discussion of the role of estuaries relative to the status of chum salmon populations), there is a considerable body of both published and unpublished information on chum salmon ecology in Hood Canal from University of Washington research from the 1960s through the mid-1980s. This research originated in studies of chum salmon population structure, behavior and ecology in Big Beef Creek (University of Washington field research station). Although this research did not specifically address the estuarine phase of chum salmon life history, it considerably expanded our understanding of the factors influencing the timing, behavior and condition of chum salmon fry emigrating from freshwater to Hood Canal (Koski 1975). In the 1970s, comprehensive studies of the potential impact of the U.S. Navy submarine base expansion at Bangor on chum salmon (among other nearshore fishes) contributed considerable fundamental information on the migratory demographics and ecology of chum salmon moving through the shoreline construction (e.g., turbidity plumes) and installations (e.g., Bax et al. 1980; Salo et al. 1980). Earlier results from components of the Bangor studies focused on chum salmon feeding ecology and prey resource assessments (Simenstad 1977; Simenstad and Kinney 1979; Salo et al. 1980; Simenstad et al. 1980; Simenstad and Salo 1982) led to more directed experimental and laboratory research on the carrying capacity limitations of chum salmon prey resources in Hood Canal supported by the National Science Foundation in the early 1980s (Simenstad et al. 1982; Simenstad and Wissmar 1984; Volk et al. 1984; Wissmar and Simenstad 1988). At the same time, Washington Sea Grant supported research on nearshore food webs also provided further insight to the food web pathways supporting juvenile salmon and their prey resources (Wissmar and Simenstad 1984; Simenstad and Wissmar 1985). While some of this research specifically included summer chum, much of it was directed toward or utilized fall chum, and often included both. It is generally assumed here that, apart from timing differences, both runs have similar life history and ecological responses to limiting factors. The following, abbreviated conceptual model of the estuarine ecology of juvenile chum salmon in Hood Canal is synthesized from this body of research.

There are several caveats that should be acknowledged to limit our interpretations from this conceptual model:

1. Much of fundamental data originates from hatchery-propagated fish, whose estuarine demography, behavior and even ecology may not be entirely applicable to wild chum, and in particular summer chum because most hatchery stocks are from normal, fall-run populations.

2. Data is more limited for early (e.g., February-early March) migrating fry, such as summer chum, than for 'normal' and late stocks, which are predominantly hatchery fish; any summer chum from late in their outmigration overlapped early 'normal' and late stock outmigrants and, if different, would have simply shown up as "noise" in the data.

3. There is little or no individual fish-based data, because chum fry had to be mass marked rather than individually tagged because of their small size.

4. There is little corroborative data on physicochemical conditions in Hood Canal at the time of most of these studies, that would provide any insight to how estuarine forcing factors (e.g., circulation, water temperature, etc.) influenced fish migration, feeding, etc.

Demography of freshwater emigration

The relationship of different summer chum life history characteristics to their response to conditions in the Hood Canal-eastern Strait of Juan de Fuca landscape is influenced by factors that affect the timing of entry into the nearshore landscape and their movement and growth through it. For this reason, even freshwater factors have some influence on the function of the estuarine landscape, and anthropogenic changes in the watershed that alter juvenile migration timing influence subsequent responses by summer chum to both natural and altered nearshore conditions in the estuary. Because chum fry gradually “grow out” of reliance on nearshore habitats and transcend to more open-water habitats over their first few weeks, factors that affect both their growth rate and the timing of this “epibenthic-neritic” (see below) transition tend to operate on the landscape scale, not necessarily within a single subestuary.

The demography (abundance of fish over time) of juvenile summer chum fry emigration to the estuary is a particularly important variable in the early life history of summer chum because variation in winter-early spring estuarine conditions can impose constraints on the eventual fish size and timing of the fishes’ migration to the North Pacific. Fish size and timing of summer chum entering North Pacific coastal waters are assumed to play a large role in determining ocean mortality. Both genetic and environmental factors affect emergence and emigration to estuary, much of which is a function of the metapopulation characteristics of spawning adults the prior fall. For instance, emigration timing is influenced by time of spawning (genetic) and late fall-winter water temperatures (environmental). A number of researchers (e.g., Koski 1975) have suggested that timing of emigration to the estuary is an adaptation to maximize survival. An alternative hypothesis that I adhere to is that diversity in emigration timing may be the actual adaptive advantage given that estuarine conditions are highly stochastic.

Adult summer chum spawn from early September to mid-October over a period of anywhere between ~45-65 days, but according to historical accounts summer chum may have entered Hood Canal streams even as early as August. Age structure may be somewhat different than 'normal' fall and latter run stocks, with slightly higher proportion of 3-ocean aged fish and somewhat smaller female spawners. Historically, summer chum were considerably much more abundant than today, from whence these data are derived, and summer chum spawner densities are now much lower compared to normal and late-run stocks. Because fecundity and egg size may indicate evolutionary mechanisms to compensate for mortality factors later in their life history, it is interesting to note that summer chum fecundity is generally higher (100 kg^{-1}) for earlier spawning fish than equivalent female size of later spawning fish. Egg size (0.2-0.5 mm dia.) would also appear to be somewhat larger for summer chum.

Despite some evidence of insignificant differences in survival rate to emergence among early, normal and late-spawning stocks, overall survival through this stage in their early life history may be slightly higher for summer chum than normal or late-run stocks due to late-winter spring freshwater flow impacts. Summer chum fry emerge form spawning redds mid-winter, between January and April. For instance, 50% of the now-extinct (since mid-1980s) early-run stock at Big Beef Creek emerges by mid-March (can even be earlier, e.g., in 1977 it was mid-February) and 90% by early April, compared to late April-mid-May, or ~35 days earlier than 'normal' and late spawning stocks (Koski 1975). Stocks on the west side of Hood Canal may be ~15 days later than the east side if Big Beef Creek was representative of the latter (Koski 1975). The duration of emergence averages ~20 days (90% emerge between 12-53 days at Big Beef Creek) and depends upon time of spawning, gravel composition, temperature, and dissolved oxygen. Temperature appears to be a critical factor, wherein early stocks require considerably more temperature units than 'normal' and late stocks by 12-13 days (11%-17%). Emergence occurs primarily during the initial hours of darkness.

The size and developmental state of summer chum fry at emergence may also differ from normal fall- or late-run chum, where fry of early spawning fish have lower length-weight condition, but lower rate of premature fry. Size increases if there is any residence in the stream. But, stream residence appears to be minimal for summer run as well as normal fall- or late-run stocks and emigration to estuary is typically immediately after emergence.

Thus, natural emigration of summer chum from one watershed to the estuary is spread out over days, if not weeks (This is in stark contrast to hatchery releases of fall chum that may be on the order of 1.8 to 4.7 x 10^6 fry released over a number hours). Instream feeding during migration is insignificant except in very large rivers. Summer chum fry school but the schools are not compact, with lots of dispersion at night. Schooling lessens as the fish approach the estuary. There is some evidence that chum fry avoid pink fry during migration.

Physiological adaptation of fry to estuarine waters

Transition from freshwater to brackish and saline waters of the estuary is relatively brief, e.g., on the order of <12 hr. Although relatively brief, the time required to adapt appears to vary with fish size (longer transition with increasing size/freshwater residence), riverflow, and the configuration of the estuary (e.g., extent of mixing zone). There have been observations that chum fry preferentially seek out the brackish (10-15‰) layer of water. This suggests that in small estuaries this adaptation zone may be a vertically-mixed, horizontal gradient within the delta, while in larger, stratified estuaries this brackish layer ("lens") may be a vertical feature that chum fry can follow for extensive distances.

Dispersion in estuary

Water circulation can play a large role in dispersion of chum fry, especially along the mainstem axis of Hood Canal and the Strait of Juan de Fuca. Under strong freshwater outflow, fish likely are pushed out with the freshwater plume unless there are extensive emergent wetlands and dendritic channels in the delta where the fry can escape high water velocities. Nearshore water movement along beaches may also influence dispersion away from the primary ("subestuary") delta, especially if the fish are pushed out into the freshwater plume. Rheotactic response may be positive or negative, depending upon magnitude of flow, because of the swimming speed limitations of fry. Initial directional behavior (dispersion vs. cross-canal) also appears to depend on size. Fry <50 mm FL have been shown to stay within or disperse to deltas, where they may reside for >5 days, while fry/fingerlings >50-55 mm FL move more into open "neritic" waters and may initially cross the Canal. Thus, an important landscape feature is the proximity to rearing habitats, where large delta habitats may serve as "attractors;" e.g., Bax (1983) experimental release of Enetai fish showing >25% remaining on Skokomish River delta after 4 days.

Directed migration through estuary

Once chum fry have initiated their migration after some (unknown, but likely <1 week on larger deltas) estuarine delta residence, migration rates along the length of Hood Canal average between 4 and 14 km d^{-1}, and generally decrease as the juvenile migration season progresses. But, given the early period of summer chum migration, migration rate may be generally high although there is not much data that is specifically applicable to summer chum fry.

There are two *modes* of migration that reflect the fish's habitat, behavior and ecology and which are directly correlated with size stanzas. Initially, "epibenthic" fry <50-55 mm FL stay very close to shore, in shallow water ~2 m deep (they are often seen swimming within 15 cm depth), when they migrate as relatively dense schools during daylight, but break up/disperse during darkness. I've termed them "epibenthic" (bottom associated) because they are closely associated with shallow water and feed primarily on epibenthic organisms. In this mode, summer chum fry migrate very close, but not necessarily in, native eelgrass (*Zostera marina*) habitat. Maximum average densities of epibenthic summer chum fry are ~1 fish m^{-2}.

In the second, subsequent mode, "neritic" fry >50-55 mm FL begin to venture into open neritic (open surface) water, especially at night. By the time they are ~60 mm FL most chum fry appear to freely migrate and feed in neritic waters.

Three factors influence the migration rate of summer chum through the Canal, the transition between epibenthic and neritic mode, and thus total estuarine residence time:

1. Foraging success, where the frequency of encounter (relative abundance) of preferred prey species for epibenthic fry may dictate their migration rate; don't know if same applies for neritic fish (see below);

2. Surface water circulation in Canal, which is generally S6N, is likely to transport neritic fry that are away from the shoreline, thus affecting the migration rate of fry >50 mm FL; and,

3. The availability of shallow water (<2 m) habitat may also influence the movement of epibenthic fry, with eelgrass serving as an important migratory corridor.

Feeding

These differences between migratory habitats and behavior of migrating chum fry in epibenthic and neritic modes are reflected in, or perhaps even caused by, their feeding ecology. Although terrestrial "drift" insects are often prominent in the diets of chum fry in the inner portion of subestuary deltas or along the margin of large deltas, epibenthic chum fry within nearshore environments feed primarily on small crustaceans such as harpacticoid copepods and other epibenthic invertebrates (e.g., small gammarid amphipods). Their diet is surprisingly specific. Typically, only two or three species of harpacticoid copepods (*Harpacticus uniremis* and *Tisbe* sp., and sometimes *Zaus* sp.) feature prominently in their diet, in contrast to several dozen harpacticoid species seemingly available to them. There is even some indication of preference for ovigerous female harpacticoids (C. Simenstad and J. Cordell, Univ. Wash.; unpubl.), which may be related to either visual prominence (*H. uniremis* egg sacks are actually brightly colored) or bioenergetic value (high nutritional value, perhaps slower escape responses by ovigerous female copepods). As chum fry grow and transcend to neritic migration, they begin to feed principally on planktonic prey such as large calanoid copepods, euphausiids, amphipods, larvaceans. Certain species (e.g., *Calanus* spp.) appear to be preferred in contrast to the overall availability of similar plankton taxa.

The relative temporal and spatial availability of some of these prey organisms may explain some of the apparent selectivity. Some are available throughout the migration period, others not; for instance, *H. uniremis*, which is univoltine, appears and declines early in the outmigration (February-April), replaced by *Tisbe* sp., which is multivoltine (April-June). Preferred species also are distributed in dense patches, perhaps enabling fish to localize on patches? Epibenthic prey are typically associated with algae, either epiphytes on eelgrass or diatom mats or other algae typical of intertidal habitats, and extremely high densities often occur in eelgrass; neritic prey tend to be diel vertical migrators (e.g., deep in the water

column during day, but migrating up into shallower water at night) or very patchily distributed on water surface (e.g., "neuston" on or just beneath the surface tension film).

Estuarine growth, nearshore-offshore transition and emigration

The relatively sharp size transition between epibenthic and neritic chum fry implies that growth (as surrogate for development of burst swimming speed, cognitive capability to adapt capture, or feeding organs such as mouth gape?) is correlated to estuarine residence time. Growth of early migrating chum fry, including some summer chum, ranges between 1% and 4% body weight per day (BW d^{-1}) but can be >6% BW d^{-1} for mid- to late stock migrants.

Residence time within Hood Canal has been found to range between 4 and 32 days; the average residence time is approximately 24 days. Their success in effectively foraging for optimum prey is likely linked to the timing and ability of chum fry to effectively make the epibenthic-neritic transition and emigrate to the North Pacific. However, it is relatively unknown whether neritic prey populations respond to the same environmental controlling factors as epibenthic prey populations. It is conceivable that neritic prey resources of summer chum may under some circumstances be on different production schedules than epibenthic prey resources, thus potential growth of the fish may differ between the two modes. As a result, foraging success may strongly affect residence time because fish that do not make the transition because of limiting prey resources and slow growth in the nearshore may not be able to tap abundant neritic prey resources by the time they migrate out of the Canal

Marine survival

Obviously, overall marine survival of summer chum is influenced by many more factors than those influencing their estuarine life history. There is some suggestion that marine survival is significantly lower (0.5%-0.8%) for early (including summer chum) migrants in Hood Canal as compared to late chum stocks (1.1%-2.6%) even though late stocks had higher proportions of 5-yr fish (Koski 1975; assuming 0.5 estimated average fishing exploitation rate). While this could be attributable to estuarine conditions, these stocks don't necessarily share the same ocean conditions. Oceanic migration routes and rearing areas of summer chum could be significantly different than normal fall- and late chum stocks due to shifts in ocean circulation between early and later entry to the nearshore ocean, e.g., dependent on shifts in California current, Aleutian low, etc. Koski's (1975) assumption of equal fishing mortality at the time may also not be valid. Statistical concordance among early/late, wild/hatchery chum recruit:spawner ratios and age class structure suggests all are influenced by same oceanic conditions, but this question is relatively unexplored.

Response of Juvenile Summer Chum to Estuarine Landscape Structure

As inferred from this conceptual model (above), responses of juvenile summer chum to the structure of the estuarine landscape depends upon the size and status (physiological, behavioral) of the fish. Fry that have not yet achieved the neritic phase are constrained to migrate along shallow-water habitats where their rate

of migration, bioenergetic status and vulnerability to predation is likely dependent upon the state of shoreline habitats. As habitat for juvenile summer chum salmon (see below) eelgrass is likely the primary migratory corridor linking the subestuary deltas in Hood Canal and the eastern Strait of Juan de Fuca. Its multi-functionality in providing both prey resources and refuge from predation suggests that it may be an important feature connecting subestuary deltas and may provide bridges between these larger rearing areas. Information from regions other than Hood Canal suggest that disruptions of contiguous natural habitats by shoreline structures (e.g., dock, piers) may modify juvenile salmon behavior, causing apparent confusion during migration and altering the intensity of schooling behavior (Simenstad et al., in prep.).

The concept and reality of limited estuarine carrying capacity for juvenile salmon is still debated (Simenstad and Wissmar 1984; Simenstad 1997b). There is some evidence that summer chum encounter limited prey resources early in their estuarine migration period, and the response is more rapid migration rates and lower growth. Whether this is driven by exogenous physical forcing, such as surface water transport, or an ecological response to availability of preferred prey (Wissmar and Simenstad 1988) remains to be determined. The potential of the latter, however, implies that both habitat loss and artificially increased densities (from earlier hatchery releases) could increase such carrying capacity responses.

Recommendations for Further Research, Protection and Restoration/ Mitigation of Estuarine Landscape Impacts

There are four major information needs required to resolve the influence of estuarine landscapes on summer chum and the potential contribution that estuarine habitat restoration and management could make to summer chum recovery:

1. Validation of critical assumptions relating estuarine habitats to summer chum;

2. Testing for mechanisms of impact on summer chum at the estuarine landscape scale;

3. Relating delta and shoreline modifications to impacts on migrating and rearing summer chum; and,

4. Assessment of restoration measures that would enhance estuarine summer chum habitat at both the subestuary delta and estuarine landscape scales.

Much of the conceptual model's description of summer chum dependence upon landscape structure, as well as the subsequent assessment of factors contributing to summer chum population declines, are inferential and not necessarily derived for summer chum. The scientific concepts of landscape ecology and the development of testable hypotheses and analytical approaches are a phenomenon of only the last few decades of ecological research. Furthermore, landscape ecology principles have been applied to estuarine habitat "landscapes" in only a few instances and only preliminarily in the Pacific Northwest. A number of critical information gaps need to be addressed to validate many of the critical assumptions that influence the interpretation of impact mechanisms and the scale of impact. For instance, the assumption that shoreline transitions between subestuary deltas are critical links among estuarine rearing habitats for summer chum

needs to be examined within the context of salmon behavior between deltas as well as the importance of shoreline habitats to the fry's successful epibenthic-neritic transition. The relationship between chum salmon and their subestuary delta and nearshore prey resources is based largely upon research on normal and late chum stocks. Thus, the assumptions that summer chum migration behavior (e.g., migration rate) is contingent upon prey availability, and that eelgrass and other mixed-fine substrate beach habitats are essential sources of preferred summer chum prey organisms, both require further validation specific to summer chum fry. Interactions and strength of the preferred prey relationship and other (e.g., physical forcing) factors influencing estuarine migration rate and residence time also need further exploration.

While mechanisms of impact at the subestuary delta scale are based on empirical evidence (albeit somewhat limited), impacts at the landscape scale are considerably less substantiated. Perhaps one of the most important issues is whether disruption of eelgrass patches inhibits the migration and survival of summer chum. The effect of eelgrass and other littoral habitat fragmentation on summer chum migration behavior needs to be evaluated and quantified if possible. In order to capture the importance of landscape structure, any investigation of habitat fragmentation should take into account within- and between-drift cell responses to habitat change by migrating summer chum. Drift cell convergences and divergences can both be areas of change in natural habitat structure, and it would provide insight to understand how juvenile salmon relate to these features.

Changes in the estuarine nearshore environment, such as habitat fragmentation, are often caused by human modification of the shoreline or underlying processes (e.g., water flow, sediment inputs) but can also occur as a result of natural processes. Thus, monitoring and assessment of sources of impact on Hood Canal and eastern Strait of Juan de Fuca shorelines and summer chum salmon must consider human stressors within the context of natural variability in estuarine landscape structure. Human stressors such as the extent and type of shoreline bulkheading and armoring, or the number and dimensions of overwater docks, must be evaluated and quantified within the context of natural variability in habitat elements (e.g., eelgrass corridors and patches) that they are known or suspected to impact. As with the evaluation of impacts on summer chum, this assessment of stressors should be organized around natural shoreline processes and geomorphic regimes such as drift cells.

Protection of existing shoreline habitat through land use regulation can be improved and would be facilitated by more specific information and understanding of current effects of shoreline development on the habitat and summer chum. Identification of shoreline areas where eelgrass beds have been impacted (and of the kinds and magnitude of shoreline developments), as well as areas where beds are not yet impacted but may be susceptible, would provide a basis for local governments to develop effective land use management actions.

Restoration and mitigation of degraded nearshore habitat should be equally important to recovery of sustainable summer chum populations as any recovery actions in freshwater or estuarine deltas. In conjunction with subestuary delta habitat restoration or mitigation, the integrity of nearshore corridors needs to be enhanced or restored through removal or modification of major man-made structures that disrupt the maintenance of natural nearshore attributes. This would involve not only removal or modification of

shoreline structure that impedes fish migration, but should also promote restoration of natural nearshore processes. Restoration/mitigation actions that will directly contribute to recovery of summer chum habitat in the nearshore include:

1. Removal of intertidal fill that has changed nearshore habitat structure, beach gradient or circulation; and,

2. Removal or modifications of docks that by shading or other disruption increase habitat fragmentation and decrease patch connectivity.

However, steps to restore fundamental nearshore processes are equally important to the long-term redevelopment and maintenance of summer chum migratory corridors. These restoration actions should include:

1. Removal of bulkheads that similarly intrude into intertidal or block sediment supply to drift cells;

2. Restoration of impacted supply and transport of beach sediments;

3. Transplanting (using adjacent source material) of eelgrass to bridge unvegetated gaps in eelgrass habitat that has been impacted by human structural or process changes; and,

4. Modification of aquaculture and other management practices that impose unnatural disturbance of nearshore habitats.

If there is one guiding concept to the ideas expressed in this document, it is that estuarine nearshore summer chum habitat is an essential segment in a continuum that bridges their natal freshwater with open ocean rearing ecosystems. Ignoring causes for decline and actions for recovery within the estuarine landscape will likely neutralize any significant recovery actions in individual watersheds or subestuary deltas. Much work remains to validate our hypotheses related to the importance of the estuarine landscape to summer chum; nonetheless, even our present-day knowledge base is sufficient to indicate that failure to act on estuarine landscape-scale recovery will postpone or prevent recovery of summer chum in Hood Canal and the eastern Strait of Juan de Fuca. Immediate actions needed to prevent further degradation of nearshore estuarine habitat include:

1. Protection of existing, unaltered shorelines – As development has spread along the Hood Canal and eastern Strait of Juan de Fuca shoreline, remaining unaltered natural shoreline segments have been diminished in number and extent. From a landscape perspective, these remnant habitat patches are likely critical to the overall integrity of summer chum rearing and migration habitat, and are thus worthy of immediate protection. New bulkhead, pier, and dock construction along the Hood Canal and eastern Strait of Juan de Fuca shoreline threatens to further fragment summer chum nearshore rearing and migration habitat. These activities should be prohibited until individual project evaluations determine that activities will not appreciably degrade or diminish nearshore habitats. Individual

projects should be evaluated in the context of overall nearshore habitat condition within the adjoining drift cell.

2. Establishment of adequate shoreline buffers – Unstable and eroding bluffs pose safety threats to homes that are constructed without adequate setbacks. Moreover, eroding "feeder bluffs" constitute an important source of sediment and organic debris for nearshore habitats. Setback distances should be conservative, designed to provide for natural erosion of feeder bluffs over time and to protect natural vegetation and homes. Again, individual cases should be evaluated within the context of overall habitat conditions within the adjoining drift cell.

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Appendix Report 3.6
Summer Chum Salmon Watershed Narratives

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Dungeness Watershed Narrative
WRIA 18.0018

Watershed Description

The Dungeness watershed is located in the northeastern corner of the Olympic Peninsula. The western portion of the City of Sequim is the only incorporated area in the watershed. The watershed drains 270 square miles beginning about 6,400 feet. It flows thirty-two miles before entering the Strait of Juan de Fuca at sea-level.

The Dungeness watershed contains a diverse array of land uses and cover types. Thirty percent of the upper watershed (80 square miles) is in the Olympic National Park. Also in the upper portion of the watershed are public and private forestlands totaling 117 square miles (43% of the watershed). This includes public lands that are mandated for uses (wilderness protection, endangered species, wild and scenic rivers, etc.) other than timber production.

In the middle and lower watershed are rural and agricultural lands occupying 56 square miles or 21% of the watershed. Of this land 16 square miles are agricultural and used for crop, hay and pastureland. Seventy to eighty percent of the agricultural land is irrigated from water diverted from the Dungeness River and area streams through an extensive network of irrigation ditches. An agricultural survey identified 604 small farms (non-commercial) and 34 commercial farms. This number is changing as farms convert to residential developments. Private woodlots, which are not intensively managed for timber production, make up another 13 square miles, (five percent of the watershed). Land under conversion, predominately from forest or agricultural to residential use covered nearly 4 square miles in 1990.

Urban areas cover 410 acres in the watershed including portions of the City of Sequim and the Sunland development, a golf course and retirement complex.

Summer Chum Distribution

Good information on spawning distributions and escapement estimates do not exist as of yet, but ripe adults have been recovered at the Dungeness Hatchery (River Mile 10.8, D. Rogers, WDFW Dungeness Hatchery, Sequim, WA pers. comm.).

Population Status

Summer chum spawning surveys were conducted in 1996 and a limited number of summer chum were observed. Peak summer chum counted was 199 fish in 1976. Since 1987, one to 60 summer chum have been observed annually during pink salmon surveys. Indications are a small self-sustaining population is present, but its status is uncertain.

Factors for Decline

The lower 10.8 miles of the Dungeness River is the primary focus of habitat restoration planning because of its high habitat value and sensitivity to disturbances originating in other parts of the watershed. The lower river is judged to be the reach most altered by and most susceptible to human alteration. Virtually all of the bank hardening (rip rap), diking, water withdrawals, gravel mining, channel alignment, bed aggradation from upriver input sources, floodplain development, riparian clearing and woody debris removal has occurred in this terminal section of river. Dikes have reduced or eliminated the floodplain, concentrating all of the energy and sediment of floods into the main channel. By inhibiting normal meander development, important stable side channel habitat has been eliminated, as well as the opportunity for the creation of new side channel habitat. Historically, removal of large woody debris (LWD) and log jams was a prominent element of flood control activities on the Dungeness River. Stable log jams are now scarce throughout this lower section of river.

The habitat above RM 10.9 has been altered by bridge crossings, sediment input associated with timber harvesting, chronic landslides and road failures. But overall the effect has been far less persistent than that occurring in the lower river.

In order for restoration efforts to succeed, sediment inputs must be in balance with the sediment transport and storage capacity of the river channel, floodplain and estuary. Increased sediment recruitment, aggradation and the loss of floodplain have been well recognized; changes at the river mouth and estuary have received less attention. Since 1855, the river mouth has moved to a location approximately 2,000 feet northeast of its earlier location, and approximately 75 acres of river delta have been formed. The river that once ran through an intertidal salt marsh estuary at its mouth, and now bisects the delta cone that has developed since diking began along the bay. The tidal prism (an important sediment transporting feature) in the vicinity of the river mouth appears to have decreased in size by over 100 acres during this time period. The implications of these changes warrant further study to assess the type of estuary-related restoration actions needed.

For a comparison of the limiting factors in this watershed to other watersheds, refer to Part Three - section 3.4, Tables 3.17 and 3.18. Limiting factors that have contributed to the decline of summer chum include:

- *Channel complexity (LWD, Channel condition, loss of side channel, and channel instability)*-Spawning, incubation and adult life stage, rated high impact. Depletion of stable log jams, loss of historical floodplain and the concentration of flows by diking and man-made constrictions have reduced channel complexity. This has resulted in an absence of stable mainstem spawning habitat and good quality pool habitat as well as a lack of high flow refugia and stream energy dissipation. Frequent channel shifting, deep scour and deposition occur after even moderate high flow events. This has been validated by post-flood salmon redd sampling data, scour chain data, aerial photo analysis, and field observations of channel location over time.

- *Riparian condition* - Spawning and incubation life stage, rated high impact. For the purposes of analysis and restoration, the lower 10.8 miles of the Dungeness River was divided into four reaches. Reach one

(RM 0.0 - 4.0) contains 45% of the riparian zone (a 200 ft wide strip) in forested buffer. Where riparian buffers are lacking, land uses include 40% in dikes, 10 % in agriculture and 5% in residential. Fifty-six percent of the forested buffer is less than 66 feet in width. Reach two (RM 4.0 - 6.6) contains 74% in forested buffer. Eighty-four percent of this buffer is in small size classes (<20 in. dbh). Twenty-three percent of the riparian buffer is less than 66 feet in width. Reach three (RM 6.6 - 8.8) contains fifty-six percent of its buffer length in forested buffer. In areas lacking in forest buffer, land uses include 26% in dikes and 18% in residential. Sixty-three percent of the forested buffer is less than 66 feet in width. Reach four (RM 8.8 - 10.8) contains 56% of its length in forested buffer. Additional land uses in areas lacking in forested buffer contains 35% in dikes and 9% in residential uses. Sixty-two percent of the forested buffer is less than 66 feet in width. Sixty-nine percent of the entire forested buffer is in small size classes (< 20 in dbh).

- *Estuarine habitat loss and degradation (diking, filling, ditches and remnant dikes, road causeways*) - Juvenile rearing and migration life stage, rated high impact. The Dungeness River delta, which is estimated to have originally covered 3.93 km^2 (970.2 ac, 2.7 mi. perimeter), is second only to the Skokomish River delta in terms of historical summer chum estuarine rearing habitat area. However, this delta has been extensively diked for agriculture, urban and commercial needs. At least 12 diked areas, totaling 0.55 km^2 (136.7 ac), now prevent tidal inundation of over at least 14% of the original delta. Diking, in conjunction with road routing, has significantly marginalized juvenile summer chum salmon migration corridors across the delta, and their access to adjacent rearing habitats.

  Two obvious intertidal fills have impacted 0.08 km^2 (18.7 ac; 1.9% of historic delta) of the delta, but it is likely that this is a gross underestimate. Three ditches or remnant dikes still impact summer chum habitat along 0.63 km (0.4 mi), constraining tidal circulation and fish movement within and across the delta. Side tributaries and tidal channels have also been extensively channelized and rerouted, as evidenced on both the eastern and the western margins of the delta. Six roads and/or causeways intrude upon or bisect the delta over a combined length of 2.27 km (1.4 mi). As with ditches and remnant dikes, modification of tidal inundation patterns likely alters fish movement and rearing potential even among the remaining emergent marshes and intertidal flats. Between 1987 and 1993, eelgrass declined by 31% in Dungeness Bay, in large measure due to the impact of ulvoid algae mats (Wilson 1993). *Ulva sp.* is commonly found to respond positively to increased nitrogen loading in marine waters. Furthermore, ulvoids within Dungeness Bay have been theorized to have forced ecosystem shifts by changing both water flow and substrate composition (Shaffer and Burge, in press).

- *Low Flow*-Spawning and adult migration life stage, rated moderate impact. Limitations in the quantity of spawning habitat and impediments to adult salmonid migration, results from a combination of irrigation withdrawals and an aggraded riverbed. Negotiations with the irrigation community have led to a series of agreements that should allow for more water to be left in the river during critical low flow period. The effects of this on habitat will be monitored.

Factors for Recovery

Restoring Dungeness River salmonid habitat will be based on reversing or reducing human impacts responsible for degradation throughout the lower 10.8 miles. Some projects will need to be applied throughout the lower river in order to restore in-channel and floodplain functions, i.e. riparian planting, large woody debris (LWD) placement or side channel creation/stabilization. Other projects will be more river-reach specific due to the location of the problem area, i.e. dikes. For a general discussion of protection and restoration strategies by habitat parameter, refer to Part Three - section 3.4.4.2, toolkit.

Restoring salmonid habitat in the Dungeness River will require the following seven elements:

- Reestablish functional floodplain in the lower 2.6 miles through dike management and constriction abatement.
- Abate man-made constrictions upstream of the COE dike (everything above RM 2.6).
- Create numerous stable long-term log jams.
- Manage sediment to stabilize the channel and reduce the risk of flooding.
- Construct and/or protect side channels.
- Restore suitable riparian vegetation and riparian-adjacent upland vegetation.
- Conserve instream flows.

In addition, initial strategies for restoring rearing and migration habitat within the estuarine delta include the following:

- Removal of remnant dikes and filling of borrow and other created ditches.
- Removal of unnecessary (e.g., recreational) roads and fills
- Reconnection of blocked and diverted channels
- Removal of tidegates and enlarging of culverts

Strength of Evaluation and Information Needs

The Dungeness Watershed has been the focus of numerous planning processes (Dungeness River Area Watershed Management Plan, Dungeness-Quilcene Water Resources Management Plan, Dungeness Watershed Analysis) and studies (Orsborn and Ralph 1992, 1994; Lichatowich, 1993). In addition, a Watershed Council (Dungeness River Management Team) and a technical work group (Dungeness River Restoration Work Group) have been working for several years to put together a restoration plan to guide efforts to restore salmonids at risk. The plan was approved by the Team in June 1998. Confidence in the assessment of habitat factors is high based on the extensive work that has been done in the watershed. Information that is still needed includes:

1. An understanding of the physical processes that affect the river's sediment supply from the upstream watershed and processes that affect the transport and deposition of sediment on the alluvial fan and estuary are crucial to the assessment of current and future conditions. The Bureau of Reclamation (BOR) has proposed to establish a sediment budget for the Dungeness River that would quantify the sediment supply from the upstream watershed and quantify aggradation rates on the alluvial fan and

estuary. Coupled with a geomorphological investigation and the application of numerical models, BOR proposes to improve our understanding of the following:

- Prediction of flooding impacts from alternative management actions.
- Prediction of scour and fill, channel meandering, and bank erosion from alternative management actions.
- Determine the existing effects of bridges on the river channel and the effects of possible bridge modifications.
- Predict the impacts on flooding from the introduction or removal of large woody debris.
- Determine the sensitivity of the river channel to sediment supply and riverflow
- Explanation of the historical channel changes.

2. A recent life history study of juvenile salmonids rearing in the Dungeness River has revealed that rearing conditions in the mainstem of the river are limited by the lack of optimum habitat. During the winter many of the juveniles move into side channels to rear and seek refuge from the high flows. Assessments should continue of juvenile use of side channels with available methodolgies of trapping and netting as well as an evaluation of the number and condition of side channels available.

3. Elevated fecal coliform bacteria counts have occurred in Dungeness Bay in recent months. The counts have been over threshold standards allowable for safe shellfish harvest set by the Federal Drug Administration and administered by the Washington Department of Health - Shellfish Program. A Dungeness Bay Shellfish Closure Prevention Response Strategy has been developed by local and State Agencies that will provide extensive monitoring to identify bacterial sources and increase enforcement through the years 1999-2000. This water quality issue has not been identified as a factor that would affect summer chum at the present time. It is suggested that as monitoring is developed that criteria be developed that would identify any problems that could affect summer chum during any part of their life history strategy e.g. adult migration and spawning, incubation, juvenile emergence and emigration, and rearing.

4. The tidal prism or area of the intertidal delta in the vicinity of the river mouth appears to have decreased in size by over 100 acres since the earliest recorded survey in 1855. The implications of these changes to sediment transport processes and summer chum rearing conditions in the estuary need to be assessed.

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Jimmycomelately Watershed Narrative
WRIA 17.0286

Watershed Description

The Jimmycomelately Creek (JCL) watershed enters Sequim Bay in the eastern region of the Strait of Juan de Fuca on the northeastern corner of the Olympic Peninsula. The JCL watershed headwaters at an elevation of about 3,800 ft., encompasses a watershed area of 19 square miles, and has a stream length of approximately 20 miles. With the exception of the lower two miles, the watershed is primarily managed by the Forest Service. Below river mile (RM) 1.0, land use is mostly rural residential and hobby farms.

Summer Chum Distribution

The current upper extent of summer chum salmon is believed to be about RM 1.5. However, summer chum may have historically occurred as far upstream as RM 1.9 at the point of an impassable falls.

Population Status

Escapement ranged from several hundred to over 1,000 in the 1980s, with one year below 100. In the 1990s escapement dropped, with 61 spawners or less in three of the past five years (Appendix Table 1.1).

Factors for Decline

A Watershed Analysis is being planned for the JCL watershed, but as of this date little information exists on the impacts from timber harvest and roadbuilding in the upper and middle watershed. Nonetheless, some information exists from a USFS habitat survey (Donald 1990). Observations regarding riparian buffer conditions throughout the JCL indicate that logging-related and road failures have continued to contribute sediment to the creek. Severe aggradation in the lower half mile of the creek has caused problems not only for fish but landowners as well. Landowner attempts to control flooding with retaining walls, anchored logs and other means have resulted in concentrated flood flows which have increased the susceptibility of redds to scour.

One of the dominant causes for the severe problems in the lower JCL is that in the early part of this century it was moved into an artificial channel. This channel was constructed too narrow, dredge spoils were placed as de facto dikes, and no provision was made to ensure that the creek was functionally tied to the estuary. The JCL has become effectively isolated from the marine environment. Vegetation non-native to salt marshes (willow, alder, cottonwood, canary grass, black berry, scotch broom) have colonized and stabilized the de facto dikes and other associated fill, eventually causing further constriction of the over-narrow stream channel. A cycle of bed aggradation, flooding and dredging has resulted. In 1997 the lowest reaches of JCL were perched spectacularly above the former estuary creating an effective barrier to spawning summer chum. Limiting factors for chum salmon in JCL include increased scour of redds and deposition of fines in the

spawning gravel as well as adult migration barriers to the spawning beds. For a comparison of the limiting factors in this watershed to other watersheds, refer to Part Three - section 3.4, Tables 3.17 and 3.18.

- *Channel complexity (LWD, channel condition, loss of side channel, channel instability)*-Spawning and incubation life stage, rated high impact. In the lower reaches riparian buffers have been reduced or eliminated, stable log jams are scarce and side channels and associated wetlands have been eliminated or cutoff from the main channel. A USFS survey completed in 1990 found 0.09 pieces of LWD per meter, a level that was considered a high impact. Pool habitat is also scare (30% by surface area, pool frequency of 9.0, Appendix Report 3.8). Confinement of the channel by bank hardening in one form or another in addition to the loss of LWD has reduced inchannel complexity resulting in aggradation, increased peak flows and increased bed scour. Scour of redds is perhaps the dominant limiting factor for summer chum in the lower reaches of the Jimmycomelately Creek. This altered hydrologic capacity of the stream has affected low flows as well, but it is not known to what extent.

- *Sediment (aggradation)*-Spawning, incubation and adult migration life stage, rated high impact. Re-routing of the channel, loss of instream channel complexity and a decrease in tidal energy have decreased the channel's ability to route sediment through the system. Increased aggradation levels have resulted in increased scour of redds. Adult summer chum have been inhibited in their migration to spawning beds due to barriers created by the aggraded bed.

- *Riparian condition* - spawning and incubation life stage, rated high impact. Within the lower 1.5 mile of summer chum spawning, the riparian buffer consists of 34% in forest, 12% in agriculture, 9% in roads and dikes, and 7% in residential land uses (Appendix Report 3.7). One hundred percent of the forested riparian buffer is in diameter classes less than 20 in. dbh. Sixty-nine percent of the forested buffer is less than 66 feet in width and 31 percent between 66 and 132 feet in width. Bank armoring in the lower half mile has also reduced the full functions of the riparian forest buffer.

- *Subestuarine habitat loss and degradation (diking, filling, log storage and associated features, road causeways*) - Juvenile rearing and migration life stage, rated high impact. The delta of Jimmycomelately Creek was estimated to originally cover 0.56 km^2 (139.4 ac; 4.3 km [2.7 mi] perimeter). Two diked areas, totaling 0.02 km^2 (3.9 ac), have impacted 2.8% of the original delta. In addition to the small diked areas, three intertidal fills have impacted 0.01 km^2 (3.1 ac; 2.2% of historic delta) of the delta. Most of these fills are associated with residential and commercial development along the Highway 101 corridor and the railroad grade.

Log storage and other associated features in two areas appear to impact a total of 0.01 km^2 (1.7 ac; 1.2% of original delta) of delta habitat. These activities are also associated with portions of the road and causeways impacts. Although dependent entirely on log storage and handling practices, there is likely low to moderate impact to benthic communities beneath and near these areas. Heavy disturbance of the benthos, and long-term input of bark and wood fragments, is likely to degrade juvenile summer chum foraging habitat. The fish may also be disrupted in their migration across the delta if they are behaviorally compromised by the floating log booms.

Three roads and/or causeways intrude upon the delta over a combined length of 0.56 km (0.4 mi). Highway 101, associated roads and the railroad grade cut off the non-tidal floodplain from the tidal delta as well as constrain circulation and fish movement among the emergent marshes and flats of the outer delta.

Factors for Recovery

A critical step for restoring stability in the Jimmycomelately will require re-establishing a functional estuary/freshwater linkage. Estuaries have long been recognized as one of the most productive aquatic environments due to their abundant food supply and wide salinity gradients. In addition to their productivity and importance to fish, estuaries provide a critical linkage for routing stream sediment into the marine environment and thereby contribute significantly to both horizontal and vertical bed stability in the lower reaches of creeks and rivers, as well as maintaining the integrity of emergent marshes on the outer deltas.

In highly functional estuaries, tidal energy is manifested and harnessed for sediment routing through a network of tidal surge plains and channels, collectively referred to as tidal basins, that serve as tributaries to the fresh stream channel. Tidal energy is effective at moving sediment where stream gradient becomes approximately zero at the marine interface. As elevations and gradient drop, stream energy declines and in this transition zone tidal surge energy increases.

Thus, sediment is transported and distributed widely into far-lower tidal elevations than channel gradient and stream energy alone would appear to allow. Linking of fresh water and tidal basins is the mechanism responsible for creating stable, slowly-evolving, complex and productive estuaries.

Perhaps no other aquatic environment on the east and north slopes of the Olympic Peninsula have been so altered by human impacts as estuaries. Diking, road and railroad grade building, and land filling have truncated significant portions of most of the region's estuaries. To date there has been no estuary restoration measure taken to specifically restore these critical functions of estuaries. Specific actions appropriate for Jimmycomelately Creek include:

- Reconnection and expansion of connections between the freshwater reaches of the floodplain and the tidal delta;
- Removal of secondary roads and railroad grade that are significant deterrents to tidal circulation and fish movement;
- Filling of remnant ditches; and
- Mitigation or elimination of the log storage and handling impacts.

Restoration in the Jimmycomelately Creek will require a complex strategy of long and short term restoration actions. A Jimmycomelately Creek Estuary Technical Working Group has been established to identify the scope of work/activities for the restoration project, as well as potential funding sources and time line. Members of the Working Group consist of the Jamestown S'Klallam Tribe, Clallam County, WDFW, Clallam Conservation District, WSU Cooperative Extension, Washington Department of Transportation and landowners in the watershed. Planning efforts include;

- Relocation of the Jimmycomelately Creek channel and reconnection to the estuary,
- Restoration of inchannel habitat and sinuousity,
- Restoration of the estuary,
- Reconnection of the floodplain to the channel
- Negotiations with Department of Transportation over an improved Highway 101 crossing over the Creek,
- Negotiations with Clallam County for a solution to the flooding and maintenance at the County Bridge site over Jimmycomelately Creek,
- Negotiations with owners of the log dump for culvert and private road realignment over a portion of the estuary, and
- Negotiations with landowners for possible land acquisition.

In addition, it has been recognized that a comprehensive solution to flooding and fisheries habitat degradation in the lower basin requires reconnection of another creek (Dean Creek) to its historic estuary, restoration of Dean Creek fish habitat east of Highway 101, and reduction of flooding hazard to Highway 101 at the Dean Creek crossing. For a general discussion of protection and restoration strategies by habitat parameter, refer to Part Three, section 3.4.4.2, toolkit.

Strength of Evaluation and Information Needs

Confidence in the assessment of habitat factors for decline is high. Information needs include:

1. An assessment of low and peak flow events (hydrologic model) in Jimmycomelately Creek.
2. An assessment of the estuary's rearing habitat conditions.
3. A comprehensive hydrologic and hydraulic analysis of drainage patterns and channel conditions throughout the lower basin.

References

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Salmon Watershed Narrative
WRIA 17.0245

Watershed Description

Salmon Creek originates on the northern slopes of Mount Zion at an elevation of 3,400 feet, has a watershed area of 19 square miles, and flows 9 miles into Discovery Bay, which is located in the eastern portion of the Strait of Juan de Fuca.

Salmon Creek merges with Snow Creek to form a common delta, although both have distinct distributary channels through to the outer delta. The historical manipulation of Salmon and Snow creeks is found in the Snow Creek narrative. The upper and mid-delta of both systems is heavily impacted by transportation, commercial and some residential development associated with the Highway 101 corridor that passes around the southern end of Discovery Bay. A railroad grade also parallels the highway in transecting the delta.

Salmon Creek is one of three major perennial creeks that drain approximately 49% of the greater Discovery Bay Watershed (Snow Creek and Contractors Creek are the other creeks). The Salmon Creek Watershed contains a diverse array of land uses but is dominated by forest cover. Land use includes both public and private forest, hay and pasture lands and residential areas. Much of the commercial forestland is in public ownership and private industrial. The largest acreage of agricultural lands occur in the lower Snow Creek Valley, through which both Salmon and Snow creeks flow.

Summer Chum Distribution

The highest density of spawners is below Uncas Road (approx. R.M. 0.7), however spawning extends up to River Mile (RM) 2.0.

Population Status

Escapements have generally been estimated to be in the hundreds, ranging up to approximately 3,000 in one year. In 1992, a supplementation program was started as a strategy to increase or stabilize the abundance to allow transfer of eggs to Chimacum Creek without adversely affecting the spawning population (Appendix Table 1.1).

Factors for Decline

The most significant issues believed to be affecting fish habitat in Salmon Creek center around changes in peak flow and low flow regimes, sediment accumulation and poor water quality in the lower reaches. Summer chum life history stages most impacted by these factors in the fresh water environment include spawning and incubation. For a comparison of the limiting factors in this watershed to other watersheds, refer to Part Three - section 3.4, Tables 3.17 and 3.18.

- *Channel complexity (LWD, channel condition, loss of side channel, channel instability*) -Spawning and incubation life stage, rated high impact. Timber and agricultural land uses in the watershed have combined to reduce or eliminate riparian buffers, large woody debris (LWD), side channels and associated wetlands. LWD levels were 0.06 individual pieces per meter, or 0.15 pieces if log jams are included, and rated as a high impact (Appendix Report 3.8). Pool habitat is limited (39% by surface area, pool frequency of 4.8) and also rated a high impact. Reductions in the type and amount of LWD have reduced habitat in the form of pools and provide for channel stability.

- *Peak flow* – Incubation life stage, rated high impact. Reduction of LWD has also reduced instream roughness that can dissipate the erosive force of floods. Excessive scour and deposition is one form of channel instability that occurs during peak flow events, leading to redd scour and egg mortality. Attempts to "fix" the channel in place by bank hardening, in one form or another, has ensured the loss of potential side channel development. Confinement of the channel by cutting off meanders and eliminating side channels and associated wetlands has altered the hydrologic capacity of the stream ensuring that peak flow events are much more severe than they were historically.

- *Riparian condition* - Spawning and incubation life stage, rated high impact. Thirty-two percent of the lower 1.5 miles of summer chum spawning distribution is in forested buffer. The dominant land use excluding forested buffers includes 43% in agriculture. Seventy percent of the forested buffer is less than 66 feet in width (Appendix Report 3.7). A habitat survey conducted by the Point No Point Treaty Council under the Centennial Clear Water Act Fund found the number of pools in relation to surface area of the creek to be very low (39% - Appendix Report 3.8). Pools are dependent on the amount of large woody debris which are in turn dependent on the extent, age, and species composition of the riparian buffer. The poor condition of the riparian buffer is a strong determinant of the poor condition of instream habitat.

- *Subestuarine habitat loss and degradation (diking and road causeways)* - Juvenile rearing and migration life stage, rated high impact. The common delta of Salmon Creek and Snow Creek was estimated to have covered 0.28 km^2 (70.4 ac; 4.5 km [2.8 mi] perimeter). Three diked areas, totaling 0.02 km^2 (5.3 ac), now prevent tidal inundation in approximately 25.3% of the original delta. Ten roads or causeways cross or encompass the delta, the most deleterious of which is Highway 101, but the railroad grade poses almost equivalent impacts because it is located in the center of emergent marsh rearing habitat. The railroad grade is likely a major contributor to muted tidal circulation across the delta, especially in emergent wetland habitat between the railroad grade and Highway 101. The total length of these various segments is ~2 km (1.2 mi).

- *Sediment (fines, aggradation*) -Spawning and incubation life stage, rated moderate impact. Very little information exists regarding the sources of sediment accumulation in the lower reaches. Land uses that confine the channel in the lower reaches increase the potential for sediment accumulation, redd scour and egg mortality. The degree to which this occurs needs to be verified. Fine sediment sampling completed in 1994 indicated 15% fines by volume less than 0.85 mm in size, rated as a moderate impact to the spawning life stage.

Factors for Recovery

A general discussion of habitat factors for decline and recovery is found in Section IV, toolkit. Knowledge of the historic conditions in Salmon Creek is limited. The historic channel probably had a more sinuous shape than we see today including connecting side channels and associated wetlands. We know that Snow Creek was a tributary to Salmon Creek in the lower reaches. Large woody debris was more abundant throughout the watershed.

- *Channel complexity and sediment* –The historic removal of large woody debris (LWD) and log jams was a prominent element of flood control activities throughout the Northwest. Stable log jams are now scarce throughout the lower reaches of Salmon Creek. Restoration of the lower channel will include restoring a sinuous channel pattern upstream of the WDFW weir, replacement of riprap entirely or with bioengineered solutions, controlling sediment inputs that are in excess of the channel's capacity to store and transport, and creating stable log jams.

- *Riparian forests* – Only 32% of the summer chum reach is cover by a riparian forest, agriculture (43%) is the primary landuse in the riparian zone. Restoration of riparian forests should follow recommendations outlined in the Riparian forest toolkit (Part Three - section 3.4.4.2). This will include replanting appropriate species, and fencing livestock out of the riparian zone (if necessary).

- *Subestuary habitat loss and degradation*- Restoration of the diked delta areas will be problematic because of the integration of the diked areas with the Highway 101 transportation corridor. Removal of the railroad grade, however, poses one of the more direct strategies to remove a significant blockage to riverine-tidal circulation and fish movement across the delta.

Strength of Evaluation and Information Needs

There has been a Federal Watershed Analysis (USFS 1996), a report produced by the Puget Sound Cooperative River Basin Team (PSCRBT 1992), and a community based watershed management plan produced in Discovery Bay (Discovery Bay Watershed Management Committee 1994). Information needs include:

1. An in-stream summer chum flow assessment.
2. An assessment of the channel's ability to accommodate peak flood flows.
3. An assessment of the extent of scour and deposition within the spawning range of summer chum.
4. An inventory of landslides, road related and other sources of sediment.
5. An assessment of the estuary's rearing habitat condition.

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Snow Watershed Narrative
WRIA 17.0219

Watershed Description

The headwaters of Snow Creek originate at approximately 3,600 ft elevation on the northeast and east slopes of Mount Zion. The stream flows east through a confined valley and then turns north into a wide valley before entering Discovery Bay. The stream is about 10 miles long and its major tributaries are Andrews Creek (inclusive of Crocker Lake) and Trapper Creek.

Since European settlement a number of changes have been made to the lower channel. At one time Snow Creek was a tributary to Salmon Creek, and emptied into Salmon Creek just upstream of Discovery Bay. The lower 0.6 miles of Snow creek was moved to the eastern edge of the valley and a new channel dredged to Discovery Bay. During flood events, Snow Creek has been known to overflow into its original channel.

The upper tributary to Snow Creek, Andrews Creek, was also diverted. Once a tributary to Lake Leland within the Little Quilcene River drainage, it was diverted into Crocker Lake. Crocker Lake had no natural outlet prior to diversion of Andrews Creek. After exiting Crocker Lake, Andrews Creek flows a short distance before entering Snow Creek at river mile (RM) 3.5.

The Snow Creek Watershed contains a diverse array of land uses but is dominated by forest cover. Land use includes both public and private forest, hay and pasture lands and residential areas. Much of the commercial forestland is in public ownership and private industrial forestland. The largest area of agricultural lands occurs in the lower Snow Creek Valley, through which both Snow and Salmon creeks flow. Sixty-four percent of the riparian zone below RM 3.0 is forested. Twenty-six percent of the riparian zone is devoted to agriculture, 4% to roads or dikes, and 2% as rural residences (Appendix Report 3.8).

At the entrance to Discovery Bay, Salmon Creek and Snow Creek form a common intertidal delta; the discussion of factors for decline and recovery below will treat this as one ecosystem component.

Summer Chum Distribution

The majority of summer chum spawn below Uncas Road (approximately RM 1.5), however there are reports that summer chum salmon spawned upstream to RM 3.0 in past years.

Population Status

Escapement until the late 1980s was estimated to be in the hundreds, varying from to over 800 spawners to three years having below 200. In the late 1980s and early 1990s, escapement dropped to very low levels, with a maximum of 33 spawners between 1989 and 1995 (Appendix Table 1.1). Strays from the Salmon Creek supplementation project may have accounted for escapements of 160 in 1996 and 67 in 1997 (fry are released from a net pen in Discovery Bay).

Factors for Decline

Channel instability and problems with peak and low flows, loss of LWD, and deposition of fines in spawning gravels are attributed as the principal habitat limiting factors. These changes have likely resulted in an increase in redd scour and a reduction of quality spawning habitat. For a comparison of the limiting factors in this watershed to other watersheds, refer to Part Three - section 3.4, Tables 3.17 and 3.18. Factors for decline in Snow Creek include:

- *Channel complexity (LWD, channel condition, loss of side channel, channel instability)*-Spawning and incubation life stage, rated high impact. In the lower reaches of Snow Creek; riparian buffers have been reduced or eliminated; stable log jams are scarce and side channels and associated wetlands have been largely eliminated. TFW ambient monitoring completed by PNPTC in 1993 found 0.07 pieces of LWD per meter, rated as a high impact (Appendix Report 3.8). The relative scarcity of pool habitat (47% by surface area, pool frequency of 5.7) was considered a moderate to high impact. Confinement of the channel by bank hardening in one form or another, in addition to the loss of LWD, has reduced in-channel complexity resulting in aggradation and an unstable channel. These factors have lead to increased channel instability with a likely increase in redd scour and egg mortality during peak flow events.

- *Sediment (fines, aggradation)*-Spawning and incubation life stage, rated high impact. Re-routing of the channel and loss of instream channel complexity have decreased the channel's ability to route sediment through the system. Increased aggradation levels have resulted in increased scour of redds. It is not known to what degree adult summer chum are inhibited in their migration to spawning beds due to barriers created by lower than normal low flow conditions as a result of the aggradation. Sediment sampling of spawning gravel, completed by PNPTC in 1994, indicated 18% fines by volume less than 0.85 mm, rated as a high impact to the spawning life stage.

- *Flow, peak and summer low*- Spawning and incubation, rated high impact. In recent years higher than normal sediment aggradation has been observed in the lower reaches. The extensive re-routing and channelization in the lower reaches of Snow Creek has lowered the channel capacity to route sediment into the bay. The increase in aggradation in the lower reaches combined with the reduced channel capacity has altered the hydrologic regime causing increased winter peak flows and lower summer flows. It is unknown how the re-routing of Andrews Creek into Snow Creek has impacted the hydrologic conditions in Snow Creek.

- *Riparian condition (species composition, age, and extent)*-Spawning and incubation life stage, rated high impact. Historic timber and agricultural land uses along with re-routing and confinement of the channel has reduced or eliminated riparian buffers along lower Snow Creek. Sixty-four percent of the riparian zone below RM 3.0 is forested. Seventy-six percent of the forested buffer is <66 ft in width. Fifty-six percent of the forested buffer is either absent or <20 in dbh (Appendix Report 3.7). The riparian forest is in poor condition

- *Estuarine habitat loss and degradation (diking and road causeways)* - Juvenile rearing and migration life stage, rated high impact. The common delta of Salmon Creek and Snow Creek was estimated to have covered 0.28 km^2 (70.4 ac; 4.5 km [2.8 mi] perimeter). Three diked areas, totaling 0.02 km^2 (5.3 ac), now prevent tidal inundation in approximately 25.3% of the original delta. Downstream of Highway 101, both sides of the bank are diked, with the estuary filled behind the right bank dike. Two roads or causeways cross or encompass the delta, the most deleterious of which is Highway 101, but the railroad grade poses almost equivalent impacts because it is located in the center of emergent marsh rearing habitat. The railroad grade is likely a major contributor to muted tidal circulation across the delta, especially in emergent wetland habitat between the railroad grade and Highway 101. The total length of these various segments is ~2 km (1.2 mi).

Factors for Recovery

In order for restoration efforts to succeed, sediment inputs must be in balance with capacity of the channel to transport and store sediment in the river channel, floodplain and estuary. This will require reducing excessive sediment input, abating constrictions to the channel and re-establishment of a functional floodplain. A general discussion of limiting factors and protection/restoration strategies is found in Part Three - section 3.4.4.2, toolkit.

Historically, removal of large woody debris (LWD) and log jams was a prominent element of flood control activities throughout the Northwest. Stable log jams are now scarce throughout the lower reaches of Snow Creek. In concert with sediment control, the creation of numerous stable, long-term log jams will increase the following functions: dissipation of stream energy to enhance channel and bank stability, creation of stable pools and riffles, reduction of bank erosion, development of physical habitat and cover for fish, and the creation of stable spawning sites. This restoration strategy can be implemented in the short term. The reintroduction of a functional riparian buffer for future recruitment of LWD will require both a protection strategy and recognition that this is an important long-term effort due to the current conditions of the riparian buffer.

In addition, a critical step for restoring stability in lower Snow Creek will require re-establishing a functional estuary/freshwater linkage. Once associated with a significant estuary, Snow Creek was relocated into an artificial channel located on the margin of its estuary. Estuaries have long been recognized as one of the most productive aquatic environments due to their abundant food supply and wide salinity gradients. In addition to their productivity and importance to fish, estuaries provide a critical linkage for routing stream sediment into the marine environment and thereby contribute significantly to both horizontal and vertical bed stability in the lower reaches of creeks and rivers.

In highly functional estuaries, tidal energy is manifested and harnessed for sediment routing through a network of tidal surge plains and channels, collectively referred to as tidal basins, that serve as tributaries to the fresh stream channel. Tidal energy is effective at moving sediment where stream gradient becomes approximately zero at the marine interface. As elevations and gradient drop, stream energy declines and in this transition zone tidal surge energy increases.

Thus, sediment is transported and distributed widely into far-lower tidal elevations than channel gradient and stream energy alone would appear to allow. Linking of fresh water and tidal basins is the mechanism responsible for creating stable, slowly evolving, complex and productive estuaries.

Perhaps no other aquatic environment on the east and north slopes of the Olympic Peninsula have been so altered by human impacts as estuaries. Diking, road and railroad grade building, and land filling have truncated significant portions of most of the region's estuaries. To date there has been no estuary restoration measure taken to specifically restore these critical functions of estuaries.

In 1995 and 1996, two phases of an early Snow Creek restoration project were implemented. These consisted of constriction abatement/floodplain creation in the lowest reaches north of Highway 101 and west of State Road 20, pool re-establishment, streambed lowering, and large woody debris (LWD) inputs. No specific estuary restoration measures were incorporated, although approximately 150 feet of old de facto dike were removed from the high salt marsh. The actions created a modest in-channel tidal surge reservoir, which in December 1996 was seen to harbor adult salmon and white sturgeon. Evidence of bedload accumulation in recent years indicates that the most important step to restoring Snow Creek is to re-establish the freshwater/estuary link.

Restoration of much of the diked areas of the delta will be problematic because of the integration of the diked areas with the Highway 101 transportation corridor. Removal of the railroad grade, however, poses one of the more direct strategies to remove a significant blockage to riverine-tidal circulation and fish movement across the delta.

Recommended restoration actions include:

- Reconnect Snow Creek to Salmon Creek within its historic channel. This would require the cooperation of state and federal agencies, Jefferson County, Jamestown Tribe, and the local landowners. If this is not possible, then establish a functional floodplain in lower reaches of Snow Creek through abatement of man-made constrictions to the channel.
- Restore sinuosity below Uncas Road (RM 1.5) through to the river mouth.
- Control sediment inputs that are in excess of the channel's capacity to store and transport material.
- Create numerous stable, long-term log jams.
- Re-introduce a functional riparian buffer for future recruitment of large woody debris.
- Remove the railroad grade in the estuary to remove a significant blockage to riverine-tidal circulation and fish movement across the delta.
- Re-integrate estuary with Snow Creek through salt marsh and mud flat restoration.
- Remove dikes on both sides of the estuarine channel and remove fill located behind the right bank dike.

Strength of Evaluation and Information Needs

There has been a Federal Watershed Analysis (USFS 1996), a report produced by the Puget Sound Cooperative River Basin Team (PSCRBT 1992), and a community based watershed management plan

produced in Discovery Bay (Discovery Bay Watershed Management Committee 1994). Information needs include:

1. An assessment of the minimum summer low flows necessary to support the desired summer chum escapement.
2. An assessment of the channel's ability to accommodate flood flows.
3. An assessment of the estuary's rearing habitat conditions.

References

Discovery Bay Watershed Management Committee. 1994. Discovery Bay watershed management plan: A community based resource management plan. Jefferson County, Port Townsend, WA.

PSCRBT (Puget Sound Cooperative River Basin Team). 1992. Discovery Bay Watershed; Jefferson and Clallam County. Jefferson County, Port Townsend, WA.

USFS (United States Forest Service). 1996. Snow and Salmon Cr. Watershed Analysis. U.S. Dept. of Agri., Forest Service, Olympic National Forest, Olympia, WA.

Chimacum Watershed Narrative
WRIA 17.0203

Watershed Description

Chimacum Creek is located in east Jefferson County, on the northeast side of the Olympic Peninsula. The mouth of the stream enters Admiralty inlet approximately five miles south of the city of Port Townsend. The Chimacum watershed is approximately 37 square miles in area, with a combined stream length of about 30 miles. In the rain shadow of the Olympic Mountains, the watershed generally receives from 35 inches of rain in its headwaters to less than 22 inches at the mouth.

Chimacum Creek originates in a number of spring fed tributaries and lakes in the forested hills, and then flows into two glacially carved lowland valleys dominated by pastureland with peat and muck soils. The surrounding hills are used for rural residences and logging of second and third growth timber, and the lowland valleys are dominated by agricultural use, primarily pastureland. Near the confluence of the east and west forks of Chimacum Creek at RM 2.9, are the towns of Chimacum, Port Hadlock, and Irondale with rapidly growing residential and commercial development. The mainstem enters a moderately confined and forested ravine below RM 1.3. At RM 0.2, the stream continues through a comparatively unimpacted estuarine lagoon, salt marsh and relatively deep inlet to the open saltwater of Admiralty Inlet. The Creek empties into a short, partially forested tidal floodplain but has no distinct tidal delta, and drains into a comparatively deep inlet that adjoins Admiralty Inlet.

Fifty one percent of the riparian zone below RM 3.0 is covered by riparian forests, most of which is in the forested ravine located below RM 1.3 (Appendix Report 3.7). Between RM 1.3 and 3.0, are minimal riparian forests and extensive landuse. Here, 49% of the riparian zone is comprised of agriculture (16%), rural residences (17%), and urban or commercial development (16%).

Summer Chum Distribution

Summer chum were documented spawning below RM 1.3, between the river mouth and Irondale road crossing, by Ray Lowrie and his Chimacum High School class from 1971 to 1976; WDFW documented summer chum in the same reach in six surveys between 1974 and 1983. Art Giles, a long time landowner on a headwater tributary of Chimacum Creek (WRIA 17.0213, Barnhouse Creek), recalls seeing chum spawning in abundance in this headwater stream decades ago (pers. comm., 1998). Because Chimacum Creek maintains a low gradient, the historic distribution may well have extended more than eight miles upstream in both valleys to the hillside tributaries (Bahls and Rubin 1996). However, for this analysis, we are basing the assessment on the more likely potential distribution below RM 3.0.

Population Status

No summer chum salmon were observed during spawning surveys conducted by the Port Gamble S'Klallam Tribe during the past five years, indicating that the population is extinct.

Spawning surveys conducted by Ray Lowrie and his Chimacum high school students between 1971 and 1976 show counts of over 100 fish for some years, however no escapement estimates were made. A reintroduction program was begun in 1996 using Salmon Creek stock.

Factors for Decline

The riparian zone and estuarine lagoon below RM 1.3 of Chimacum Creek remains in good condition with large second growth conifer and no development within the ravine. Above the ravine, 95% of the wide, low gradient, glacial valley was ditched for pasture and cropland beginning in the 1920s (Bahls and Rubin 1996). These upstream changes in land use have impacted the habitat in a number of ways. For a comparison of the limiting factors in this watershed to other watersheds, refer to Part Three - section 3.4, Tables 3.17 and 3.18.

- *Fine sediment* - incubation life stage, rated high impact. In-stream habitat has been severely degraded by a combination of upstream impacts. Siltation from de-forested and channelized segments has degraded spawning gravel conditions. In addition, the collapse of the Irondale road crossing (RM 1.3) and its fill in 1983 caused downstream sedimentation and "cementing" of the stream gravel making redd construction difficult for salmon (Ray Lowrie, pers. comm., 1996). These conditions have improved in recent years, but percentage of fine sediment in the spawning gravel remains high (M. Kennedy, stream restoration volunteer, private comm.).

- *Peak flow, freshwater wetland loss, and channel instability* - incubation life stage, rated moderate impact. The historic conversion of the Chimacum lowland valleys from beaver pond wetlands and forested bogs to pasturelands may increase the duration and magnitude of winter flood flows. The valley still serves as a flood reservoir however it is suspected the valley may release floodwater more rapidly than the previous beaver-pond dominated valley. Areas around Chimacum, Port Hadlock, and Irondale are rapidly urbanizing, with an expected increase to the severity of winter floods from impervious surfaces.

- *Low flow* - spawning life stage, rated moderate-low impact. Water withdrawal for irrigation and loss of wetlands in the Chimacum valley may impact summer chum survival, with a more severe impact in years when the summer dry season overlaps the Summer Chum spawning season (mid August to mid October). DOE has an administrative closure to further surface water diversion (DOE 1998).

- *Water quality* - spawning and incubation life stage, rated moderate-low impact. The good condition of this riparian zone helps reduce high summer stream temperatures coming from the agricultural valleys upstream. Temperature monitoring (1998) at the mouth indicates that while state AA standards were exceeded in July, by the end of August temperatures averaged 14°C and declined to below 12°C by the end of September. Chum prefer spawning temperature of 12-14°C, this is considered a moderate to low impact. Dissolved oxygen at the river mouth averaged between 9.3 and above 10 mg/L, with the state AA standard of 9.5 mg/L. In 1998, fecal coliform at RM 1.1 averaged just below the state AA standard of 50 FC/ml (Al Latham, JCCD). However, in dry years when the summer dry season overlaps the fall spawning season, stream temperatures may be a significant impact.

- *Riparian forest* - spawning and incubation life stage, rated low impact. The riparian forests range from absent or severely degraded, to those in advanced stages of recovery. Most of the degraded riparian forests occur between RM 1.3-3.0. Above RM 1.3, riparian forests are small diameter (<12 in), deciduous or grass dominated and narrow in extent (<66 ft). Below RM 1.3, the forested strip is wide (>200 ft), mixed conifer/deciduous, and with a medium average diameter (12-20 in). Since summer chum is primarily found below RM 1.3, it is these forest conditions that reduced the overall riparian impact from moderate/high to low.

- *Subestuary habitat loss and degradation* - Juvenile rearing and migration life stage, rated moderate impact. Out of all the 20 sub-estuaries, this was the only one that did not have a road directly across or shortly upstream of the subestuary. However, south of the river mouth approximately 30 ac of tidal marshland was filled, probably in the late 1800s. A road now crosses most of the fill, but ends at the river mouth. There are no other roads, jetties or dikes, dredged, ditched or excavated areas evident in this comparatively small, 0.02 km^2 (5.2 ac, 1 km [0.6 mi] perimeter) delta. Historically, the bay at the mouth of the creek was used for log storage.

Factors for Recovery

The following recommendations are provided to allow recovery of Summer Chum habitat in the lower river. Jefferson County should realize that designating Chimacum, Port Hadlock, and Irondale as Urban Growth Areas under the Growth Management Act should consider the impact to the lower Chimacum Creek and subestuary. A general discussion of protection and restorations strategies for each habitat factor is found in Part Three - section 3.4.4.2, toolkit.

- *Fine sediment and water quality* - Investigate replacement of the fill and culvert at the Irondale Road crossing with a bridge to remove the possibility of future culvert failure. The costs and benefits of this project should be weighed against other Chimacum Creek projects. Within the valley, re-establish forested riparian zones along the east and west forks of Chimacum Creek to reduce high summer water temperatures and input of fine sediment.

- *Peak flow and summer low flow* - Restore wetlands where possible to increase flows in the summer and to help reduce the impacts from peak flows in the winter. There are several areas where wetland and beaver pond restoration could be accomplished without impacting existing farmers. Conduct an extensive assessment of surface and groundwater withdrawals to determine the extent of impact on summer low flow and to identify potential remedies. Locate and monitor potential runoff sources from impervious surfaces. Monitor the potential impacts from peak flows to the channel bed with scour chains.

- *Riparian forest and LWD* - Protect the riparian and wetland habitat in the entire lower 1.3 miles (below Irondale Road) and upstream areas that are still forested and in good condition. The Jefferson Land Trust and WDFW are currently working to acquire conservation easements to protect key salmon refugia throughout the watershed.

- *Protect tidal floodplain and estuary* - The subestuarine fill site has been highlighted by conservation groups for aquisition and restoration. Upstream of the mouth, the subestuary narrows and enters a canyon where it is relatively unimpacted by development. The subestuary in the canyon is contiguous with the undeveloped lower 1.3 miles of riparian forest. This entire stretch should be protected with easements or outright purchase.

Strength of Evaluation and Information Needs

The Chimacum Watershed Coho Salmon Restoration Assessment (Bahls and Rubin 1996) provides a fairly thorough base of information upon which to evaluate the status of habitat for summer chum salmon. However, because most of the impacts on summer chum habitat are an indirect result of upstream habitat changes, confidence in the assessment is moderate.

The following are research and monitoring needs:

1. Determine the impact (if any) on surface and groundwater withdrawals on summer low flow.
2. Conduct scour monitoring to determine the magnitude of peak flow on redd scour.
3. Annual monitoring of fine sediment both above and below Irondale Road.
4. Continuous temperature monitoring at regular intervals below RM 3.0.

References

Bahls, P. and J. Rubin. 1996. Chimacum watershed coho salmon habitat restoration assessment. Port Gamble Tribe Fish Management, Kingston, WA.

WDOE (Wash. Dept. of Ecology). 1998. Needs assessment for the Eastern Olympic Water Quality Management Area. Wash. Dept. Ecol., Olympia, WA.

Little Quilcene Watershed Narrative
WRIA 17.0076

Watershed Description

The Little Quilcene watershed drains to Quilcene Bay. It is bounded by Snow Creek to the North, Donovan and Tarboo Creek to the east, Big Quilcene to the south, and Dosewallips to the west. The Little Quilcene has a watershed area of 30 square miles, total mainstem length of 12.2 miles and combined tributary length of 81.2 miles. The upper 1/3 of the watershed lies within the basalt-rich Crescent formation, and is primarily Forest Service land. Watersheds of this rock type are steeply dissected with limited anadromous habitat (e.g. similar to most of west Hood Canal from the Big Quilcene south). Port Townsend diverts water (9.6 cfs water right, with a 6 cfs mimimum instream flow requirement at diversion) at RM 7.1 to Lords Lake Reservoir on Howe Creek, which is removed from the watershed (USFS and WDNR 1994). This water right is junior to a total of 5 cfs water rights held by landowners in Quilcene. Lords Lake (generally filled during April and May) is used to supplement Port Townsend water diverted from the Big Quilcene when flows decline below the Big Quilcene minimum instream flow level, or when the Big Quilcene contains excessive suspended sediment during floods (USFS and WDNR 1994, S. Cupp, US Forest Service, pers. comm. 1994). WDOE has an administrative closure to further surface water diversion (WDOE 1998).

From approximately RM 7.0 to the mouth, the watershed is composed of unconsolidated glacial sediment layers interbedded with siltstone and sandstone, and alluvium deposited by the river (Grimstad and Carson 1981). This portion of the watershed contains extensive low-gradient anadromous habitat and associated development for agriculture, homes, and the town of Quilcene. The Little Quilcene reaches the town of Quilcene at about RM 1.0.

Sixty percent of the riparian zone below RM 3.0 is developed (major landuse are 33%-Agriculture, 11% roads or dikes, 8% rural residences and 6% forestry, Appendix Report 3.7), which is considered a high impact. The lower 0.8 miles contains dikes and bank armoring for floodplain residences. Dikes, roads, and ditches impact the tidal delta.

Summer Chum Distribution

Summer chum spawn in the mainstem up to RM 3.0, however most spawning occurs below RM 1.8. It is unlikely summer chum use tributaries such as Leland Creek due to low summer flows.

Population Status

Escapement declined in the 1980s from the several hundreds with occasional escapements of over one thousand to less than two hundred spawners. From 1989 through 1994 escapement was 12 spawners or less, with four years of 0 or 1. An improvement in escapement to 265 was seen in 1996. In 1997 escapement dropped to 29, but was again 265 in 1998 (Appendix Table 1.1). The recent increases may be affected by the summer chum supplementation project in the immediately adjacent Big Quilcene River.

Factors for Decline

The Little Quilcene is similar to the Big Quilcene in terms of factors for decline. The habitat is in poor condition, especially below RM 0.8. Factors for decline are: water withdrawal, low channel complexity, estuarine diking, channel aggradation, and young or absent riparian vegetation. These factors are not separate, but interact to increase pressure across all life stages. For a comparison of the limiting factors in this watershed to other watersheds, refer to Part Three - section 3.4, Tables 3.17 and 3.18.

- *Low flow*-Spawning life stage, rated high impact. Mean annual flow for the Little Quilcene is 54 cfs, with low flows of 5 to 13 cfs (Jamestown S'Klallam 1994). The Little Quilcene is overallocated during low flow periods. The City of Port Townsend and local landowners combined hold a total of 14.6 cfs in water rights. The 5 cfs of senior irrigation water rights held by local landowners in the lower river is downstream of the 6 cfs the City of Port Townsed is required to maintain in the river. The City of Port Townsend (and Port Townsend Paper) "divert very little if any water from the first part of September until the first major rains in the fall" (Stan Cupp, Port Townsend Paper, pers. comm.). The impact of water withdrawal on fish habitat needs further investigation. For eastern Jefferson County, water consumption is expected to increase 78% (over 1990 levels) by the year 2020 (Jamestown S'Klallam 1994). Developing water resources in the glacial deposits of the Little Quilcene, where continuity may exist between surface water and groundwater, may further reduce already low summer flows. An aquifier study for the Big Quilcene was inconclusive on the connectivity between the Big Quilcene and the glacial deposits between the Big and Little Quilcene (Schwartzman 1998). This relationship needs further study for both rivers.

- *Channel complexity*-Spawning and incubation life stages, rated high impact. From habitat surveys, the Little Quilcene has (within the summer chum range) 32% pool, 0.1 pieces of LWD/m., and an average of 5.3 channel widths between pools. Together these numbers translate into highly degraded channel habitat. A 1932 survey of the Little Quilcene noted many logjams and six areas of beaver activity in the lower 10 miles (Amato 1996). Most of these logjams are gone. Six hydraulic permits for LWD removal were issued from 1989 to 1995 alone (WDFW HPA database). The stream catalog reported ditching of the Little Quilcene below RM 0.8 (Williams et al. 1975). Portions of the south riverbank currently are hardened with riprap (B. Rot, pers. comm.).

- *Subestuary habitat loss and degradation*-Juvenile rearing and migration life stage, rated high impact. Undiked river mouths are connected to multiple slough channels, which are heavily utilized by summer chum for spawning and rearing. Dikes along the river and paralleling the coast south of the river mouth have physically isolated the river channel from slough habitat. Through aerial photo analysis, we estimate that 25% of the historic delta area of approximately 230 ac. is diked along the western margin of the delta. These diked areas appear to be controlled by at least two tidegates. Four road or causeway segments totaling 0.45 mi. in lineal extent, may constrict or prevent natural tidal inundation of adjoining wetlands. Ditches, filling and dredging were not detected in the delta. No docks, log storage, jetties or other structures are evident.

- *Riparian forest*-Spawning and incubation life stage, rated high impact. Seventy percent of the forested buffer contains small trees (<12 in dbh), 51% is deciduous dominated or has no riparian forest, and 60% is <66ft in width and/or sparsely vegetated (Appendix Report 3.7). The riparian forest was first harvested in the early 1900s by the Otto Beck Logging Company to supply the Green Shingle Mill located in Quilcene (Amato 1996). At the time, the floodplain between and surrounding the Big and Little Quilcene rivers was mostly old growth cedar swamp and forest. The mill was closed in 1915 when the accessible cedar had been harvested. In addition to historical effects, bank armoring, home building, and agriculture in the 100-year floodplain has reduced the extent of functional riparian forest.

- *Sediment*-Spawning and incubation life stage, rated moderate impact. The channelized and diked lower river near the mouth has resulted in channel aggradation and avulsions at least three times in the past six years below RM 0.3, leaving the main channel dry for at least several weeks (R. Johnson, WDFW, Port Angeles, WA, pers. comm.). The channel avulsed both north and south of the diked mainstem. While very little information exists regarding potential sediment sources within the watershed, failing Forest Service roads, diking of the estuary and lower channel, and increasing percentage of impervious surfaces are suspected primary factors.

Factors for Recovery

A general discussion of protection and restoration strategy for each factor is found in Part Three - section 3.4.4.2, toolkit.

- *Low flow*- the extent of water usage or draw-down by Port Townsend during August and September and its potential impact to summer chum spawning is unknown. While DOE has the river on administrative closure, the IFIM study currently in progress is expected to provide information needed regarding relative impacts of surface water withdrawal on fish. Further study is needed on whether there is a relationship between well use and instream flows.

- *Property buyout and floodplain easements*-protect the few remaining spawning areas in the lower three miles with intact riparian forest and good instream habitat. Identification of these areas could be done with the assistance of the Hood Canal Salmon Sanctuary group.

- *Construction permits*-below RM 0.7, the 100-year floodplain has extensive development to the south of the river. Except for a road, the north side is relatively undeveloped, although at least one lot is for sale. A recent springtime flood crossed this property. In areas of high channel migration, bank hardening follows floodplain development. The county should restrict future development to areas outside of the 100-year floodplain throughout the summer chum zone.

- *Riparian forest and LWD*-educate local landowners on the importance of LWD to channel complexity and connected forested floodplains. Encourage farmers and residential landowners to plant conifer where the forest is absent or dominated by deciduous species, and discourage removal of LWD (see Riparian Forests toolkit, Part Three - section 3.4.4.2).

- *Channel aggradation*-conduct an assessment using the methodology in the Watershed Analysis mass wasting module to determine the source of channel aggradation.
- *Restoration of estuarine diked areas* — Purchase or obtain an easement of estuarine property, remove dikes (both paralleling the channel and the coast south of the channel) and restore connection to the lower floodplain and subestary. In addition, restore channel sinuosity through this reach. This represents a potential recovery of over 25% of the historic juvenile summer chum rearing and migration habitat in this estuary (see Subestuarine toolkit, Part Three - section 3.4.4.2). Conversion of fill road causeways to pile causeways may also recover additional estuarine habitat.

Strength of Evaluation and Information Needs

Confidence in the assessment is high given the channel habitat surveys, riparian forest and landuse data for the Little Quilcene, coupled with the large amount of data for the nearby Big Quilcene River.

Information needs include:

1. An understanding of the range of annual summer low flows (given withdrawal) and whether these are adequate to support recruitment goals. If not, what flow is necessary and what density will the existing range of flows support.
2. A study to look at well development and instream flows.
3. A sediment source assessment for the watershed.
4. A study evaluating the relative effect of road fill causeways on the creation and maintenance of tidal slough channels, and the feasibility of dike removal in the lower channel and estuary.

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Big Quilcene Watershed Narrative
WRIA 17.0012

Watershed Description

The Big Quilcene watershed drains to Quilcene Bay in west Hood Canal, and is bounded by the Little Quilcene to the north, the Dungeness to the west, and the Dosewallips to the south. The Big Quilcene has a watershed area of 68 square miles, total mainstem length of 19 miles, and combined tributary length of 80 miles. Thirty percent of the Big Quilcene watershed (headwater) is contained in the Buckhorn wilderness. Below the Buckhorn, the Forest Service, State, and private forestland owners manage most of the remaining watershed for timber production. This portion of the watershed is steep, with relatively weak, easily eroded rock. The Big Quilcene is a tier II Key Watershed under the President's Forest Plan (FEMAT 1993). The primary water source for the City of Port Townsend (30 cfs water right) is diverted at RM (river mile) 9.4. This is a consumptive use and is diverted out of the basin. The majority of water supports the operation of a paper mill.

Below RM 4.8, the channel gradient moderates and flows through an increasingly wide floodplain. This area of small private land blocks occupies about 5% of the watershed. The Quilcene National Fish Hatchery (QNFH) is located at RM 2.8, and utilizes water from both the Big Quilcene and nearby Penny Creek. On the Big Quilcene, they have a 15 cfs water right with an additional 25 cfs when flows in the mainstem at the hatchery exceed 50 cfs from July 1 to February 28, and 83 cfs from March 1 to June 30 (Jamestown S'Klallam 1994). This water is removed from the Big Quilcene for about 1/2 mile between the hatchery intake and outlet. Penny Creek is a 25 cfs water right (Jamestown S'Klallam 1994).

Thirty eight percent of the riparian zone to RM 4.8 is occupied by landuse, primarily roads or dikes (21%) and agriculture (10%, Appendix Report 3.7). The channel below RM 0.8 is diked, and portions of the channel between RM 0.8 and 4.8 has been dredged, diked, or the bank armored. The Big Quilcene flows through the town of Quilcene at approximately RM 0.8.

Summer Chum Distribution

Summer chum spawn in the mainstem up to RM 2.8 where the hatchery weir prevents further passage, however most spawning occurs below RM 1.0. Since historical summer chum distribution may have extended up to RM 5.0 on the mainstem (USFS 1994), we examined habitat conditions up to RM 5.0. It is unlikely that summer chum historically spawned in tributaries such as Penny Creek due to low summer flows.

Population Status

Escapement dropped substantially from estimated in the thousands prior to 1978 to estimates below on hundred from 1983 to 1991, excepting 1998 with 120 spawners in 1988 (Appendix Table 1.1). In 1992, the Tribes, WDFW, and U.S. Fish and Wildlife Service initiated a 12-year brood stocking program (USFWS

1994). The run was to be restarted from chronically low levels while chum habitat was enhanced to support a wild run.

Factors for Decline

The Big Quilcene watershed has historically been managed for timber, water, and hatchery fish production. The habitat is in poor condition, especially below RM 1.0 where the primary summer chum spawning grounds are located. The habitat is degraded due to: water withdrawal, low channel complexity, sub-estuarine modifications; sediment accumulation, and a young deciduous dominated (or absent) riparian forest. The decline in summer chum cannot be attributed to any one factor. These factors are not mutually exclusive, but interact to increase pressure across all life stages. For a comparison of the limiting factors in this watershed to other watersheds, refer to Part Three - section 3.4, Tables 3.17 and 3.18.

- *Low flow*-Spawning life stage, rated high impact. Discharge (below the diversion dam from August 15 to October 15, for the years 1994-1996) ranged between 23 to 82 cfs, with an average of 30 cfs. Summer chum return to the Big Quilcene in late August and spawn from September to mid-October. In 1994, Port Townsend agreed to reduce or halt water withdrawal during low flow to maintain a minimum of 25 cfs in the channel for fish. Prior to that, an informal arrangement between the dam operators and the hatchery ensured enough water was maintained in the river to satisfy QNFH needs. Another issue is whether residential or municipal wells have the potential for drawing down the Big Quilcene R. (e.g. whether hydrologic continuity exists between the two). A recent study was not conclusive (Schwartzman 1998).

- *Channel complexity and floodplain loss*-Spawning and incubation life stage, rated high impact. In the late 1950s, the lower Big Quilcene between RM 1.0 and 3.8 was a narrow, meandering, single thread channel, with reported good levels of LWD, pools, and an intact riparian forest. A structurally complex channel reduces the amount of stream energy available to scour summer chum redds. The channel is now wide, braided and in poor condition. The river has few, widely spaced pools (31% spaced at 5.1 channels widths between each pool) and relatively few pieces of LWD (0.16/m, PNPTC 1992, Appendix Report 3.8). While simplification of the channel has occurred throughout the past 150 years, substantial LWD has been removed since the 1960s by the WDF stream improvement division and also by local landowners. More recently, dredging (RM 2.5 to 2.2, and below RM 1.0), bank armoring, and dike construction/enhancement (RM 2.5 to 2.2, and below RM 1.0) have increased the continuing channel instability. During floods, a diked reach will have more energy to scour redds to a greater depth than an undiked reach at the same location. In 1995, Jefferson County removed a portion of the northern dike below RM 0.5 as a first step to reduce flooding hazard and improve fish habitat (Williams et al.1995). Channel cross sections surveyed annually by the Jefferson County Conservation District since 1993 indicate a period of channel stability during that time. Further dike removal is needed (Jefferson County 1998).

- *Subestuary habitat loss and degradation*-Juvenile rearing and migration life stage, rated high impact. Undiked river mouths are connected to estuarine slough channels, which are utilized by summer chum for spawning and rearing. Dikes along the river and paralleling the coast south of the river mouth have physically isolated the river channel from slough habitat. Summer chum juveniles are unable to access estuarine rearing habitat without first moving into Quilcene Bay. Predation impacts resulting from this

are unknown. In the past 100 years, the river mouth has extended 1,700 ft out into the bay due to dredging and diking (Jefferson County 1998). Dikes obstruct about 21% of the estimated historic delta area of 125 ac (3.5 mi. perimeter). About 3% of the historic delta is filled for commercial and residential use in four areas primarily located in the southeastern corner of the delta. About 2% of the historic delta area was excavated for one large pond (for use by waterfowl). No dredging in the intertidal zone, or road causeways in the delta has been observed. One piledike 0.45 mi. in length apparently runs along the outer edge of the southern delta. The influence of this piledike on estuarine circulation cannot be determined. No other log storage, docks, or other structures were observed in the delta.

- *Sediment aggradation*-Spawning and incubation life stages, rated high impact. Forest Service logging roads built between the 1940s and 1960s were poorly located and constructed, and form a dense network in the middle and upper watershed. Road failure in these areas, with sediment accumulation in the lower watershed has been a chronic problem since the late 1960s. The simplified, braided channel (below RM 4.0) with its lower capacity to transport sediment (see channel complexity) has increased local channel movement and bank erosion which has introduced even more sediment into the system. Recovery begins with stabilization or removal of roads and properly sized culverts on Forest Service land as outlined in the Watershed Analysis (USFS 1994). This is needed to permanently reduce the amount of sediment moving through the Big Quilcene watershed.

- *Riparian forest*-Spawning and incubation life stage, rated moderate impact. A mature conifer dominated riparian forest will provide stable LWD to create structurally complex channels. Forty four percent of the lower Big Quilcene is <12 in dbh, 49% is deciduous dominated or has no riparian forest, and 45% of the forested portion of the riparian zone is < 66 ft in width (Appendix Report 3.7). Recruitment of stable LWD in the future is poor to moderate due to the composition of the surrounding riparian forest. If the primary chum spawning reaches below RM 2.8 were only considered, the riparian forests would rate a high impact. Diking, agriculture, harvest and erosion in the lower Big Quilcene have reduced the extent of functional riparian forest.

Factors for Recovery

A general discussion of the protection and restoration strategies for each habitat factor is presented in Part Three - section 3.4.4.2, toolkit.

- *Low flow* – Starting in 1998, there was a cooperative effort to monitor stream flows for spawning availability between the City of Port Townsend, QNFH, Port Townsend Paper Co., USFWS, Jefferson County Conservation District, and Tribes. An IFIM study recently conducted by WDFW in part leaves unanswered whether the given low flow of 25 cfs is sufficient to provide good spawning habitat for summer chum. The IFIM flow recommendations were well in excess of late-summer flows in the absence of withdrawal, and likely are better applied to fall chum. Data developed by the cooperative effort will be needed to assess the impacts of stream flow on spawning habitat.

- *Dike removal and property buyout in lower mile* – This relates to the low channel complexity and sediment aggradation habitat factors. The 1998 Big Quilcene Flood Management Plan (Jefferson County 1998, and

Williams et al. 1995) calls for dike removal and property buyout from willing landowners on the north side of the river below RM 1.0. Floodplains are dynamic through time; to maintain residences on them has high social, economic, and ecological costs. The dike north of the channel would be set back to the outer extent of the 100 year floodplain. Additionally, the Linger Longer bridge would be extended as a causeway to allow floodwaters to flow underneath it and across the floodplain. Finally, a sinuous channel pattern found in lowest portion of the channel should be restored. These projects may have several benefits, 1) sediment aggradation will be reduced in the mainstem below RM 1.0, with the capacity to store sediment on the floodplain. In turn, flooding hazard to the houses to the south of the main channel should be lowered. 2) The level of energy or stream power for a given flood level will decline with the dissipation of floodwaters across the floodplain, thereby reducing the erosive energy available to scour summer chum redds.

- *Subestuary habitat loss and degradation* – Removal and dike setback could restore up to about 21% of the currently obstructed historic area of the delta to juvenile and adult summer chum use. Filling the excavated pond would restore an additional 3% of the historic area. Restoration of a sinuous channel pattern through the estuary would increase the amount of habitat for chum. Where feasible, intertidal fills could also be removed. Combined, these actions could reconnect the mainstem to tidal estuarine channels, heavily utilized by chum.

- *Floodplain easement purchase (RM 1.0-2.8)* – The channel is active and dynamic between RM 1.3 and the Hwy 101 bridge at RM 2.5. Bank armoring or riprap is utilized in this reach to stabilize streambanks, although the Jefferson County Conservation District has tried more recently other techniques more favorable to habitat. Allowing or creating a sinuous channel pattern will over time decrease stream power, increase available habitat, and reduce aggradation downstream. A potential mechanism to achieve channel migration is outright property buyout or purchase of floodplain easements from willing property owners. Riverbank within each easement area could be stabilized with LWD and the easement area planted with conifers to serve as a future source of LWD to the channel. Several areas of relatively intact riparian forests exist between RM 1.0 and 2.5. Protection of these forests would provide a base to develop a riparian forest protection plan.

- *Sediment aggradation* – The 1994 Big Quilcene watershed analysis identified mass wasting from Forest Service roads as a causal factor for downstream channel aggradation. Removal of LWD, diking, and channel manipulations, especially below the QNFH, is also considered important (Jefferson County 1998). The City of Port Townsend has entered an agreement with the Forest Service to pursue road obliteration in the portion of the watershed upstream of the diversion dam. The Forest Service has successfully obliterated roads in several sub-basins, however with budget cuts, district office closures, and staff cutbacks it is unclear whether they will be able to complete all the mass wasting prescriptions outlined in the watershed analysis. This needs to be monitored. In addition the severity of the scour problem (due to unstable sediment) in the lower river has not been quantified. The USFWS has the equipment and personnel to study this problem, it is hoped that funding will continue to be available.

Strength of Evaluation and Information Needs

The Big Quilcene is one of the most intensively studied watersheds in Hood Canal. Confidence in the assessment of habitat factors for decline is high. Further research and monitoring is needed on the following:

1. Determine whether new wells located in Quilcene between the Big and Little Quilcene will impact streamflow.
2. Continue to develop an understanding of the relationship of actual streamflow to the availability of summer chum spawning habitat.
3. Study the depth of bed scour throughout the summer chum zone concentrating on the diked areas below RM 0.8.
4. Update mass wasting data on Forest Service land from the 1994 watershed analysis and determine the extent that presciptions have been followed and whether the prescriptions have met resource objectives.

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Dosewallips Watershed Narrative
WRIA 16.0442

Watershed Description

The Dosewallips River is located in east Jefferson County on the west side of Hood Canal. The Dosewallips is one of the largest watersheds contributing to Hood Canal, draining 122 square miles and containing 28 miles of mainstem and 140 miles of tributary habitat (Williams et al. 1975). It is bounded on the north by Big Quilcene and Dungeness watersheds, and on the south by the Duckabush watershed. The Dosewallips originates within the Olympic Mountains, flows east through steep terrain, and enters Hood Canal near the town of Brinnon. The middle portion of the watershed lies within the basalt-rich Crescent formation, while various sandstone, siltstone, and slate bedrock formations predominate at the headwaters. Relatively limited glacial and alluvial deposits occur along the lower 13 miles of the river. Average annual discharge is 446 cfs (range 67-13,200 for the years 1931-1958) at RM 7.1. There are two annual runoff peaks, one occurring November-February associated with winter rain, the other occurring in May-June associated with spring snowmelt (USFS 1999).

The lower 2.5 miles of river is fringed by a large floodplain that has been developed for agricultural and rural residential use. Of all Hood Canal tributary deltas, the Dosewallips is second only to the Skokomish in size, historically occupying 444.6 acres (~1.8 km^2) with a perimeter of 6.2 miles (9.9 km). North of the river mouth numerous blind tidal sloughs (e.g. Walcott Slough) drain a large estuarine marsh.

The upper 60% of the Dosewallips watershed is undeveloped and protected within Olympic National Park, while the middle 30% of the basin is in Olympic National Forest. As with other west Hood Canal watersheds, private land is concentrated along sensitive lower reaches of the river where use is dominated by pastureland, residential development, and clearcut logging. Dosewallips State Park occupies land on the south side of the river near the mouth, and the town of Brinnon is located to the north within the floodplain-delta area. Brinnon has no municipal water system; area residents derive domestic water supplies from individual wells, stream diversions, or shared community water sources. Since 1956, the City of Port Townsend has maintained a permitted water right to continuously divert 50 cfs of water from the Dosewallips for municipal use, but this application has never been acted upon (USFS 1999). Currently, DOE has an administrative closure on further surface water diversion for the July-October period. Minimum flow criteria have been developed for the Dosewallips River but have not been formally adopted (Rushton 1985). The river is classified as a AA surface flow waterbody by the state and is not listed on EPA's 303(d) list of impaired and threatened waterbodies, though available ambient water quality data is limited (USFS 1999).

Historically, intensive timber harvest and fires have impacted the slopes of the middle and lower watershed. Logging in the watershed began in 1859 using ox teams, and progressed to the use of railroads and splash dams near the turn of the century, which were replaced by trucks after 1920. A splash dam built by the Sims Logging Company at the head of the Dosewallips canyon (RM 3.2) in 1917 was in operation for 9-10 years. When water was released, most logs that had been accumulated behind the dam were flushed all the way to Hood Canal suggesting the erosive power of these releases was likely catastrophic for salmon and their

habitat in the lower river. Railroad logging of the watershed was extensive; the longest railroad line was built on the south side of the river from Brinnon upstream to approximately RM 10.2. Most logging and road building on Forest Service land has occurred in the Rocky Brook subwatershed; between 1920 and 1990, 65% of this subwatershed was clearcut. A landslide inventory based on historic and current aerial photos identified 128 slope failures that have occurred in the watershed since 1939. Forty-five (35%) were road- or harvest-related with 42 (93%) of these occurring within Rocky Brook subwatershed (USFS 1999).

While only 14% of the entire Dosewallips watershed has ever been harvested for timber, 80% of the lower river area (upstream to the confluence with Rocky Brook) has experienced forest harvest (which encompasses the range of summer chum; USFS 1999). Beginning in the late 1800s, the lower river valley (below RM 3.0) was converted from a forested floodplain, rich in LWD jams, side channels and active floodplain wetlands to a channelized river with adjacent pastureland (Amato 1996). The subsequent construction of Highway 101 and development of Brinnon resulted in further wetland loss and degradation, severed the connection of numerous tidal channels to the river and/or Hood Canal, and reduced tidal circulation in the estuary. Nearly 20% of the present-day riparian zone (by area) below RM 4.3 has been negatively impacted by recent land use (7% rural residences, 6% urban/commercial, 3% agriculture, and 3% forestry - Appendix Report 3.7).

Summer Chum Distribution

Natural barriers and high stream gradients limit summer chum to the lower 4.3 miles of the Dosewallips and most spawning occurs below RM 2.5.

Population Status

Summer chum population data only extends back to 1972 for the Dosewallips River. During the 1970s, most escapements were over 1,000 spawners, extending up to over 3,000. Escapement decreased during the 1980s to less than 100 spawners in some years and several hundred in other years. In 1995 and 1996 escapement rose to almost 3,000 and 7,000, respectively, then declined again to 47 and 336 spawners in 1997 and 1998, respectively (Appendix Table 1.1).

Factors for Decline

Low channel complexity, estuarine habitat loss and degradation, riparian degradation, and freshwater wetland loss appear to be the principal factors associated with the decline of summer chum in the Dosewallips watershed. For a comparison of the limiting factors in this watershed to other watersheds, refer to Part Three - section 3.4, Tables 3.17 and 3.18.

- *Low channel complexity* - Spawning and incubation life stages, rated moderate-to-high impact. Much of the lower river below RM 3.0 has been simplified since the late 1800s by the placement of riprap, dike construction, large woody debris removal, the scouring action of splash dam operation, and conversion of floodplain to pastureland and residential development. As a result, the river has become isolated from its floodplain, reducing habitat diversity and complexity and likely reducing the availability of stable

spawning gravels. Recovery has been hampered by the loss of riparian forests, which supply LWD to the channel, and the continuing removal of LWD from the channel by area residents (Frissell 1998, T. Labbe, pers. comm.). Although there are no habitat surveys for the lower mainstem, 1990 US Forest Service surveys of Rocky Brook Creek identified 23% of the habitat area in pools and 0.02 LWD pieces/m in the lower half mile of stream which indicate degraded habitat conditions (P. DeCillis, USFS, pers. comm.). Additional surveyed reaches upstream also had poor habitat conditions (29% of habitat area in pools and 0.08 LWD pieces/m) While summer chum are not known to utilize Rocky Brook Creek, it is the largest tributary to the lower Dosewallips mainstem (entering at RM 3.6) and its degraded condition has important consequences for the supply of LWD and sediment to the lower river.

- *Estuarine habitat loss and degradation* - Juvenile rearing/migration life stage, rated moderate-to-high impact. At least six diked areas, totaling 68.5 ac, now occupy 15.4% of the original summer chum rearing and migration habitat in the Dosewallips estuary. Four tidegates appear to regulate or prevent tidal inundation in these diked areas, and one ditch or remnant dike 0.4 mi long attests to past attempts to further eliminate tidal inundation along the delta face. Ten road causeways totaling 1.2 mi bisect or fringe the delta, the most deleterious of which is the cross-delta routing of Highway 101. Construction of the highway, and the subsequent development that derived from it, essentially cut off most of the secondary tidal channel connectivity across the delta, in particular two major distributary channels that appear to have historically linked with the river higher in the delta. Five identifiable fill areas associated with residential or agricultural development occupy 2.5 ac (0.6% of historical delta area). One aquaculture or similar modification to the delta surface covers 2.9 ac (0.6%), but it is not evident whether this poses a significant loss of estuarine habitat function, which depends to a large degree on the scale and frequency of disturbance to important habitat areas such as eelgrass.

- *Riparian degradation* - Spawning and incubation life stages, rated moderate impact. Logging of old-growth floodplain forests, river channelization, and the expansion of pasture and residential areas along the lower 3.0 miles of the river has reduced both the original extent of riparian forests and the potential for LWD recruitment to the channel. Fifty-one percent of the forested buffer below RM 4.3 is dominated by small trees (<12 in dbh) and 41% is deciduous dominated, but 52% is mixed conifer and deciduous forest and 58% of the forested buffer is greater than 132 ft wide (all percentages by length). An analysis of riparian LWD recruitment potential completed by the Olympic National Forest, (Quilcene Ranger District) as part of the Dosewallips Watershed Analysis also identified fair (28%, by stream length) to poor (40%) riparian conditions predominating along the entire length of the river mainstem. In addition, the analysis found poor (91%, by stream length) riparian LWD recruitment potential along Rocky Brook Creek, indicating that LWD volumes in stream channels both in and above the zone of summer chum use will remain limited in the foreseeable future, unless mitigation occurs (USFS 1999). For additional information about riparian data refer to Appendix Report 3.7.

- *Floodplain loss* - Spawning and incubation life stages, rated moderate impact. As discussed above, the loss of floodplain forests, most of which were probably forested wetlands, likely reduced the amount and diversity of habitats and increased the impact of flood flows on mainstem channel habitat due to lost floodwater storage capacity.

Factors for Recovery

Like other west Hood Canal watersheds, the Dosewallips is remote from the development pressures, such as exist on the Kitsap peninsula, and much of its headwaters are managed by public agencies with mandates for the conservation of indigenous species. However, development pressures are highly concentrated in and around the lower 3.0 miles of river, where most summer chum use occurs. Nonetheless, compared to other Hood Canal and eastern Strait of Juan de Fuca watersheds, prospects for the recovery of summer chum are good. A general discussion of protection and restoration strategies for each habitat factor is found in Part Three - section 3.4.4.2, toolkit.

Recovery of summer chum in the Dosewallips watershed requires:

- Protection and restoration of the lower 3.0 miles of river mainstem and associated riparian floodplain habitats. Properties in the lower floodplain should be targeted for acquisition or conservation easements from willing landowners, and conifers replanted in the riparian zone. This sensitive lower river area should also be examined for potential placement of engineered logjams to enhance channel complexity and stabilize spawning gravels for summer chum. The proximity and number of private residences in this lower river area also creates a potential for harassment and poaching, which needs further investigation (Frissell 1998).

- Restoration of full tidal action to the various extant and failed diked wetlands across the delta. Numerous tidal channels north of the river mouth could be reconnected to the river and/or Hood Canal, which would restore valuable summer chum rearing habitat.

Strength of Evaluation and Information Needs

Very little habitat research or survey data exists for the Dosewallips River, although it represents one of the larger, more pristine watersheds in Washington with high salmon production potential. A U.S. Forest Service watershed analysis has been completed for the Dosewallips. Most of the conclusions presented here are based on observations of current habitat conditions in the watershed and knowledge gained from historical research and habitat studies conducted in other similar watersheds, such as the Big Quilcene watershed. The strength of the evaluation is thus rated moderate to low due to the lack of site-specific field studies. Information needs include:

1. Habitat surveys of the lower river.
2. An assessment of channel stability as it relates to spawning and incubation life stages.
3. A study of impacts to estuarine rearing potential from road causeway constrictions (necessarily involving multiple estuaries under various degrees of impact).

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Duckabush Watershed Narrative
WRIA 16.0351

Watershed Description

The Duckabush River is located in east Jefferson County on the west side of Hood Canal. The Duckabush watershed is over 75 square miles in area and contains 25 miles of mainstem and 91 miles of tributary habitat (Williams et al. 1975). It is bounded on the north by the Dosewallips and on the south by the Hamma Hamma watersheds. The river originates in the Olympic mountains, flows east through rugged terrain, and enters Hood Canal approximately four miles south of the town of Brinnon. As in the Dosewallips watershed, various sandstone, siltstone, and slate bedrock formations predominate at the headwaters while the lower two-thirds of the watershed lies within the basalt-rich Crescent formation. Limited alluvial deposits are found along the lower 6 miles of river. Average annual discharge is 411 cfs (range 46-9,240 for the years 1939-1996) at RM 4.9. There are two annual runoff peaks, one occurring in November-February associated with winter rain, the other occurring in May-June associated with spring snowmelt (USFS 1997). The Duckabush enters Hood Canal over a broad 291.6-acre (1.2 km^2) estuarine delta with minimal development impacts excepting those associated with Highway 101.

The upper 80% of the watershed is protected in Olympic National Park and the Brothers Wilderness (Olympic National Forest). Timber extraction is the dominant land use in the lower watershed, on both National Forest and private lands. Timber harvest on lands now under National Forest ownership began in the 1900s. Webb Logging Company of Brinnon, Washington built a logging railroad up the Duckabush and logged most of lower and middle portions of the watershed in the early 1900s. Before the construction of the logging railroad, timber was harvested as far upstream as Collins Campground (RM 5.5) and floated downstream to Hood Canal. There is limited evidence that early loggers may have employed splash damming in the Duckabush (USFS 1997). The WDF Stream Improvement Division removed logjams and dynamited falls in the river between 1955 and 1970 with the goal of improving fish passage (Amato 1996). More recently, dense recreational homesite development has occurred along the lower 1.5 miles of the floodplain.

The Washington Department of Ecology maintains an administrative closure on issuance of further surface water rights for the July-October period, and minimum flow criteria have been developed for the Duckabush River but have not been formally adopted (Rushton 1985). The loss of LWD and development on the floodplain has confined the river to a single channel and reduced channel complexity. Overall road density in the watershed is low (0.6 mi/mi^2), but moderately high road densities in the lower Duckabush (2.2 mi/mi^2) subwatershed (which encompasses the range of summer chum) has contributed to mass wasting (USFS 1997). A landslide inventory based on historic and current aerial photos identified 191 slope failures that have occurred in the watershed since 1939, 133 (70%) of which were located within the lower half of the watershed. At least 65 (34%) were road- or harvest-related and 148 (78%) were estimated to have delivered sediment to stream channels (USFS 1997). As in other Hood Canal watersheds, road causeways impact the Duckabush estuary, disrupting tidal circulation, and impeding fish access to productive marsh and slough habitats. Nearly 25% of the riparian zone (by area) below RM 3.0 is now developed (12% urban/commercial, 9% rural residences, and 3% roads/dikes).

Summer Chum Distribution

A series of cascades between RM 3.5 and 4.5 confine summer chum to the lower river. Most summer chum spawning occurs in the lower 2.2 miles.

Population Status

Escapement estimates shows the Duckabush falling from levels in the thousands in the 1970s to less than 100 spawners in several years of the 1980s. In the 1990s, escapement estimates increased to the hundreds, except for 2,650 spawners in 1996, overall still substantially less than the 1970s (Appendix Table 1.1).

Factors for Decline

Low channel complexity, estuarine habitat loss and degradation, riparian degradation, and freshwater wetland loss appear to be the principal factors associated with the decline of summer chum in the Duckabush watershed. For a comparison of the limiting factors in this watershed to other watersheds, refer to Part Three - section 3.4, Tables 3.17 and 3.18.

- *Low channel complexity* - Spawning and incubation life stages, rated moderate-to-high impact. The channel in the lower river appears to have been greatly simplified since the late 1800s by the scouring action of splash damming, large woody debris removal, and conversion of floodplain to pastureland and residential development. As a result, habitat diversity and complexity has been reduced (e.g. side channels, deep holding pools, and stable spawning gravels). A 1992 U.S. Fish and Wildlife Service survey from RM 0.2-2.3 found 31% of habitat area in pools and sparse woody debris, which indicates degraded habitat conditions (Tabor et al. 1993).

- *Subestuarine habitat loss and degradation* - Juvenile rearing/migration life stage, rated moderate impact. Two diked areas totaling 3.9 acres occupy 2.8% of the original 291.6 acres of estuarine delta habitat; these diked areas are located at the northern edge of the delta in association with residential development adjacent to a small distributary channel. An estimated 0.2 acres (0.1%) of the historic delta area has been filled and two ditches or remnant dikes with a total length of 0.3 mi are evident in the delta. Five roads traverse the delta at various locations, the most obvious of which is Highway 101. The total length of these road segments is 0.4 mi but, as in the Hamma Hamma and other Hood Canal estuaries, these relatively short road causeways represent a major disruption to tidal circulation and fish movement across emergent wetlands in the mid-reaches of the delta.

- *Riparian degradation* - Spawning and incubation life stages, rated moderate impact. Logging of old growth floodplain forest and conversion to pasture and residential areas has greatly reduced the potential for LWD recruitment to the channel. The forested buffer below RM 3.0 is dominated by medium-sized (12-20 in dbh) trees (66%) and, to a lesser degree, small (<12 in dbh) trees (32%). As in the Dosewallips, mixed conifer and deciduous forests predominate (57%) in the riparian zone, and 59% of the forested buffer is >132 ft in width (all percentages by length). By comparison, another analysis of riparian LWD recruitment potential along both the mainstem river and tributaries in the lower Duckabush watershed

identified approximately 36% of riparian forests in poor condition, 11% in fair condition, and 53% in good condition (USFS 1997). These data suggest that riparian forests are currently degraded, and that near-term LWD volumes in stream channels both in and above the zone of summer chum use will remain limited in the foreseeable future, unless mitigation occurs.

- *Floodplain loss* - Spawning and incubation life stages, rated moderate impact. As discussed above, the loss of floodplain forests, most of which were probably forested wetlands, likely reduced the amount and diversity of habitats available to summer chum during freshwater life stages.

Factors for Recovery

Like other west Hood Canal watersheds, the Duckabush is remote from development pressures such as exist on the Kitsap peninsula, and much of its headwaters are managed by public agencies with mandates for the conservation of indigenous species. As a result, prospects for the recovery of summer chum are good.

Recovery of summer chum in the Duckabush watershed requires:

- Protection and restoration of riparian floodplain habitat along the lower 2.5 river miles. Properties in the lower floodplain should be targeted for acquisition or conservation easements from willing landowners, and conifers replanted in the riparian zone. This sensitive lower river area should also be examined for potential placement of engineered logjams to enhance channel complexity and stabilize spawning gravels for summer chum.

- Restoration of a natural tidal distributary channel system across the waist of the estuarine delta through reduction of the impact from the Highway 101 road causeway. Rerouting or refitting of the Highway 101 road causeway across the delta would be required to significantly restore natural tidal circulation and juvenile salmon movement across or residence in the delta. One of the diked areas in the northern delta represents a viable opportunity for restoration of juvenile summer chum foraging habitat through the dike removal and recovery of full tidal inundation.

Strength of Evaluation and Information Needs

Very little research has been conducted on fish habitats of the Duckabush watershed, although it represents one of the larger, more pristine watersheds in Washington with a high salmon production potential. Only recently, a U.S. Forest Service watershed analysis was completed. Only cursory habitat survey data exist for the lower Duckabush River (Tabor et al. 1993). Information needs include: 1) more detailed habitat surveys of the lower river, 2) an assessment of channel stability as it relates to spawning and incubation life stages, and 3) a study of impacts to estuarine rearing potential from road causeway constrictions (necessarily involving multiple estuaries under various degrees of impact). Most of the conclusions presented here are based on observations of current habitat conditions in the watershed and knowledge gained from historical research and habitat studies conducted in other similar watersheds, such as the Big Quilcene watershed. The strength of the evaluation is thus rated moderate to low due to the lack of site-specific field studies.

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Hamma Hamma Watershed Narrative
WRIA 16.0251

Watershed Description

The Hamma Hamma River is located in northern Mason and southern Jefferson counties on the west side of Hood Canal. It is bounded on north by the Duckabush, on the west by the Skokomish, and on the south by the Lilliwaup and Jorsted creeks watersheds. The Hamma Hamma watershed is about 85 square miles in area and contains 18 miles of mainstem and 93 miles of tributary habitat (Williams et al. 1975). Average annual discharge is 559 cfs (range 39-6,010 for the years 1951-1979). There are two annual runoff peaks, one occurring in November-February associated with winter rains, the other occurring in May-June associated with spring snowmelt (USFS 1997). The Hamma Hamma originates on the rugged, eastern flank of the Olympic mountains and flows east through steep, forested terrain and drains to Hood Canal at the town of Eldon. Except for limited sandstone, siltstone, and slate bedrock formations at the headwaters, most of the watershed is underlain by the basalt-rich Crescent formation with glacial and alluvial deposits along the river mainstem. Below RM 1.5 the stream gradient moderates and the river is flanked by a large floodplain. A major tributary, John Creek, enters at RM 1.4. The lower 0.6 miles of the Hamma Hamma is tidally influenced, and at high tide at least one small secondary channel connects the mainstem with a large tidal marsh, just north of the main channel.

Nearly 95% of the watershed is under public ownership; 60% is managed public forestland and 34% is protected in National Park or designated wilderness. Private lands (5%) are concentrated in the productive, low-elevation areas near the river mouth, and are managed primarily for timber extraction (Heller et al. 1995). By the 1930s most of the Hamma Hamma watershed had been logged. Removal of LWD from streams began as early as 1953 when John Creek was cleared or diverted around 12 log jams. In 1958 the Hamma Hamma Logging Company constructed a dike, placed riprap, and dredged the mouth of the river to facilitate log booming (Amato 1996). A 1930s-era Hamma Hamma Logging Company timber cruise map reveals a 0.3-mile-long side channel at RM 0.8 that is no longer in existence.

Manipulation of and timber salvage from the main channel has continued to the present, and some of this activity has been illegal (T. Labbe personal observation, Cook-Tabor 1996). Recent, intensive clearcut logging has likely contributed to severe landslides along John Creek and in the mainstem gorge area (~RM 2.0; USFS 1997). Overall road density in the watershed is low (1.4 mi/mi^2), but in the lower Hamma Hamma subwatershed (inclusive of John Creek) road densities are high (2.4 mi/mi^2), approaching a level where significant channel degradation can be expected to occur (USFS 1997).

Most of the floodplain area along the lower 1.5 miles of the Hamma Hamma has been appropriated for agricultural and residential uses. Cattle have unlimited access to most of this lower river area. Thirty-five percent of the riparian zone (by area) below RM 3.3 has been impacted by recent intensive landuse (23% forestry, 10% agriculture, 2% rural residences). The Washington Department of Ecology maintains an administrative closure on issuance of further surface water rights for the July-October period, and minimum flow criteria have been developed for the Hamma Hamma River but have not been formally adopted

(Rushton 1985). An application by Mason County Public Utility District for hydroelectric development on the Hamma Hamma is currently pending before the Federal Energy Regulatory Commission.

Summer Chum Distribution

Natural barriers and high stream gradients in the middle and upper watershed limit anadromous fish use to the lower 2.0 miles of the Hamma Hamma River and to the lower 1.8 miles of John Creek. Most summer chum spawning occurs below RM 1.8 in the Hamma Hamma and below RM 0.3 in Johns Creek.

Population Status

Through the 1970s, escapement for the Hamma Hamma River and John Creek combined numbered in the thousands. After 1979, spawner density declined to hundreds per year. In the 1990s, estimated spawner density fluctuated from below 100 to several hundred (Appendix Table 1.1).

Factors for Decline

Low channel complexity, estuarine habitat loss, altered sediment dynamics, and riparian degradation appear to be the principal habitat factors associated with the decline of summer chum in the Hamma Hamma watershed. These factors are interrelated and the most severe impacts have occurred in the extreme lower reaches of the river, where summer chum spawning is concentrated. For a comparison of the limiting factors in this watershed to other watersheds, refer to Part Three - section 3.4, Tables 3.17 and 3.18.

- *Low channel complexity* - Spawning and incubation life stages, rated moderate-to-high impact. Dredging and bank hardening of the lower mainstem, and removal of LWD from streams have reduced overall channel complexity in the Hamma Hamma watershed. A 1996 U.S. Fish and Wildlife Service habitat survey in the Hamma Hamma River from approximately RM 0.5-1.8 found 50% of the habitat area in pools, which is considered fair, and a LWD loading of 0.13 pieces/m which is considered poor (Appendix Report 3.8). In the lower 1.8 miles of John Creek, pools composed 51% of the total habitat area (rated fair) but LWD loading was extremely poor (0.06 LWD pieces/m). Most notably, large-sized, "key" LWD pieces, which are important habitat-forming and stabilizing features of larger rivers, were completely absent from the Hamma Hamma mainstem suggesting streambed instability that may result in redd scour during peak flow events is a potential threat to summer chum in this watershed (Cook-Tabor, 1996).

- *Subestuarine habitat loss and degradation* – Juvenile rearing/migration life stage, rated moderate-to-high impact. Over 13% of the estimated 368.5-acre historic delta is diked in three areas, accounting for a loss of 48 acres of summer chum rearing habitat. One filled area in the outer, southern corner of the delta accounts for a loss of 3.2 acres (1% of historic delta habitat). An estimated 2.4 acres (0.6% of historic delta area) of the mainstem distributary channel where it crosses the outer intertidal area has been dredged, and at least seven areas of aquaculture or other modifications of the delta surface are apparent from contemporary aerial photographs which total 2.2 acres (0.6% of historic delta area). Three jetties or piledikes, totaling 0.4 mi in length, are evident in the delta. In addition, eight road and causeway

segments, totaling 1 mile in length, transect the delta, the largest of which is the Highway 101 causeway that has caused a direct loss of habitat and constrained tidal action and fish movement across the delta. The apparent isolation of the north bank estuarine marsh from the main river by dredging and dike/road causeway construction at the river mouth has eliminated the connectivity of the river with a critical chum rearing habitat. As a result, outmigrant chum fry are routed directly into deepwater habitat and must reenter the marsh from the east (via Hood Canal). The impacts of such a severe transition on summer chum outmigrants are unknown but they are suspected to be severe given the relative vulnerability of this life stage to physiological stress, predation, etc.

- *Altered sediment dynamics* - Spawning and incubation life stages, rated moderate impact. Sediment aggradation in the lower reaches of John Creek has resulted in a series of high gradient cascades near the mouth where, in some years, subsurface flow occurs during late summer when summer chum adults return to spawn. In addition to impeding/delaying the spawning migration of summer chum into John Creek, there is potential for the dewatering of redds. Logging-induced landslides in upper John Creek have likely resulted in elevated sediment delivery rates to the channel.

- *Riparian degradation* - Spawning and incubation life stages, rated moderate impact. Reduction in riparian forest extent has eliminated recruitment sources for LWD. Moreover, a shift from conifer-dominated to alder-dominated riparian communities (along lower John Creek, in particular) has diminished the longevity and stability of LWD in the channel because alder logs are typically smaller than conifers and do not persist as long in streams. As a result, sediment is not retained in John Creek but routed downstream to accumulate near the mouth (see above). Forty-eight percent of the forested buffer below RM 3.3 is composed of small (<12 in dbh) trees, and 45% is dominated by medium-sized (12-20 in dbh) trees. Conifer- (48%) and deciduous-dominated (26%) buffers prevail along the lower river, and while 58% of the forested buffer is >132 ft wide, the remaining 42% is sparse and/or <66 ft. In combination, these conditions represent moderate impact.

Factors for Recovery

Like other west Hood Canal watersheds, the Hamma Hamma is remote from the development pressures such as exist on the Kitsap peninsula, and much of its headwaters are managed by public agencies with mandates for the conservation of indigenous species. One family owns most of the land in the lower reaches of the river where summer chum spawn, simplifying potential public-private conservation efforts. Although summer chum habitat in the Hamma Hamma is presently degraded, conditions are not beyond recovery and past escapement estimates indicate the watershed has strong summer chum production potential. A general discussion of protection and restoration strategies by habitat factor is found in Part Three - section 3.4.4.2, toolkit.

Recovery of summer chum in the Hamma Hamma watershed requires:

- Protection and restoration of riparian forests to guarantee long-term LWD recruitment sources. Illegal logging and timber salvage from riparian forests should be stopped and sites evaluated for the placement of engineered log jams to enhance channel complexity. In particular, logging of steep

erosive areas in John Creek and the mainstem along the gorge (beneath the powerlines) should be curtailed as both these areas have high landslide risk.

- Reconnection of the river with the north bank estuarine marsh and reclamation of floodplain habitats for fish. Elimination of both inhibitors to migration and restoration of rearing habitat will be essential to provide significantly greater access to natural delta habitats. This would require removal of training dikes and cessation of dredging in the lower tidal distributary channel. Ultimately, however, rerouting or refitting the Highway 101 road causeway across the delta may be required to completely restore tidal circulation, and juvenile salmon rearing habitat in the Hamma Hamma delta.

- Reduction of upstream impacts of sedimentation (particularly in John Creek) by preventing logging on potentially unstable slopes and removing and repairing roads with surface erosion or landslide hazard problems.

Strength of Evaluation and Information Needs

Confidence in this assessment of habitat factors is moderate to high. To date, a U.S. Forest Service watershed analysis and a Puget Sound Cooperative River Basin Team report have been completed. The U.S. Fish and Wildlife Service surveyed the anadromous extent of both the Hamma Hamma and John Creek in 1996. Information needs include: 1) an assessment of the north bank estuarine marsh and its potential for reconnection with the main river, 2) an analysis of the sediment budget in John Creek, 3) an assessment of channel stability as it relates to spawning and incubation life stages, and 4) a study of impacts to estuarine rearing potential from road causeway constrictions (necessarily involving multiple estuaries under various degrees of impact).

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Lilliwaup Watershed Narrative
WRIA 16.0230

Watershed Description

The Lilliwaup Creek watershed is located in northern Mason county on the west side of Hood Canal. It is bounded on the north by Eagle, Jorsted, and Hamma Hamma watersheds, on the west by the Skokomish, and on the south by the Sund Creek watershed. The Lilliwaup watershed is underlain by the basalt-rich Crescent formation, is 17.9 square miles in area, and contains 6.9 miles of mainstem and 10.8 miles of tributary habitat (WDF 1975). Lilliwaup Creek is fed by extensive wetlands associated with Price Lake and upper Lilliwaup valley, totaling over 910 acres (Heller et al. 1995). The remaining upper and middle watershed stream habitats are generally high gradient. Below a large falls at RM 0.7 the stream flows through a large well-developed floodplain before draining to Hood Canal at the town of Lilliwaup.

Managed public forestland accounts for 89% of the watershed area. Private managed forestland (7%) and residential lands (2%) are concentrated to the east, along Hood Canal (Heller et al. 1995). Little historical information on the watershed exists, but it is known that by the early 1930s, the entire Lilliwaup watershed had been logged (Amato 1996). Much of the lower floodplain/estuarine area has been developed for transportation and residential use. At some point during the 1960s or 1970s, a section of stream immediately above Highway 101 was straightened and dredged to route floodwaters away from homes on the east side of Lilliwaup Creek (R. Endicott, personal communication). A hatchery operates on lower Lilliwaup Creek and rears summer chum for release into the creek (summer chum salmon are the only species released into the stream). There are 7.75 cfs of issued surface water rights in the watershed (Heller et al. 1995). A private landowner operates a small hydroelectric power facility immediately below Lilliwaup Falls (RM 0.7). Road density in the Lilliwaup Creek watershed is 2.9 mi/mi^2, significantly above the level where channel degradation can be expected to occur (USFS 1997). Forty-eight percent of the riparian zone (by area) below RM 0.7 is developed (28% roads, 20% agriculture).

Summer Chum Distribution

Lilliwaup Falls at RM 0.7 blocks anadromous passage upstream. Spawning surveys indicate summer chum utilize the full extent of the anadromous zone in Lilliwaup Creek.

Population Status

Annual escapement from 1971-1978 ranged from several hundred to over one thousand spawners. Since that time escapement has never exceeded 300, and generally is below 100 spawners (Appendix Table 1.1).

Factors for Decline

Riparian degradation, estuarine habitat loss, and low channel complexity appear to be the principal habitat factors associated with the decline of summer chum in the Lilliwaup Creek watershed. All of the factors

discussed below cover immediate impacts to the area accessible to summer chum but upstream cumulative impacts such as altered stream flow characteristics or sediment/LWD delivery rates may also be important. For a comparison of the limiting factors in this watershed to other watersheds, refer to Part Three - section 3.4, Tables 3.17 and 3.18.

- *Riparian degradation* - Spawning and incubation life stages, rated moderate impact. Agricultural and residential development along the lower reaches of Lilliwaup Creek has reduced the extent and altered the age and species composition of the riparian forest. Elimination of riparian forests has decreased LWD recruitment sources for both the creek and estuary. Seventy-nine percent of the forested buffer below RM 0.7 is dominated by medium-sized (12-20 in dbh) trees of mixed conifer and deciduous composition, and 21% lacks a buffer altogether. Fifty-two percent of the buffer is >132 ft in width, while 48% is <66 ft wide and/or sparse.

- *Subestuarine habitat loss and degradation* - Juvenile rearing/migration life stage, rated moderate impact. Of the estimated 48.2 acres of historic delta, one diked area associated with a fish hatchery accounts for a loss of 1.5 acres (3.1% of historic delta area). Fill for residential development on the south side of Lilliwaup estuary accounts for a loss of 1.2 acres (2.6%), and a human-excavated pond at a fish hatchery represents a loss of 0.5 acres (1%). In addition, the 0.12 mi long Highway 101 causeway that bisects the delta has constrained the estuarine distributary channels of Lilliwaup Creek, eliminated habitat area, and likely altered overall estuarine function by altering tidal circulation. Although a relatively small percentage of the historic delta area has been impacted, the location of these habitat alterations has likely contributed to their disproportionately large effect on the overall functional value of Lilliwaup estuary as juvenile rearing and transition habitat for summer chum.

- *Low channel complexity* - Spawning and incubation life stages, rated moderate impact. No habitat survey data exist for Lilliwaup Creek. Based on aerial photo interpretation and communication with local residents, approximately 600 feet of Lilliwaup Creek at RM 0.2 was straightened and dredged. The lack of LWD in both the creek and estuary also contributes to reduced channel complexity, and raises the potential for channel instability and redd scour during peak flow events.

Factors for Recovery

Limited spawning habitat likely restricted the summer chum population in Lilliwaup Creek under natural conditions. Human occupation and use of the Lilliwaup Creek floodplain and estuary has probably further diminished summer chum production potential. On a positive note, the large wetlands of upper Lilliwaup valley that appear to guarantee sufficient stream flow for returning summer chum remain intact and functional (Heller et al. 1995).

Recovery of summer chum in the Lilliwaup Creek watershed requires:

- Restriction of human activity in the lower floodplain to allow for the reestablishment of riparian forests and natural recruitment of LWD to the main channel.

- Restoration of a natural tidal distributary channel system across the waist of the estuarine delta through reduction of the impact from the Highway 101 road causeway.
- Protection of the Washington DNR-owned wetlands in upper Lilliwaup valley, which sustain summer flows in Lilliwaup Creek.

Strength of Evaluation and Information Needs

Confidence in this assessment of habitat factors is moderate. To date, a U.S. Forest Service watershed analysis and a Puget Sound Cooperative River Basin Team report have been completed but little additional information exists. Information needs include:

1. An assessment of the condition and role of upstream wetlands in sustaining summer low flows suspected to be critical to summer chum.
2. A survey of lower Lilliwaup Creek to collect baseline habitat information.
3. An assessment of channel stability as it relates to spawning and incubation life stages.
4. A study of impacts to subestuarine rearing potential from road causeway constrictions (necessarily involving multiple subestuaries under various degrees of impact).

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Skokomish Watershed Narrative
WRIA 16

Skokomish and North Fork Skokomish River 16.0001, Purdy Creek 16.0005, Weaver Creek 16.0006, Hunter Creek 16.0007, South Fork Skokomish River 16.0011, Richert Springs 16.0010, Vance Creek 16.0013

Watershed Description

The Skokomish River is the largest river system in the Hood Canal Basin of Puget Sound with a watershed area of approximately 240 square miles comprised of 80 miles of mainstem and over 260 miles of tributaries. The Skokomish watershed drains the southeast corner of the Olympic Mountains and enters the southwest end of Hood Canal known as the Great Bend between the towns of Union and Potlatch creating the largest subestuary and intertidal delta in the Hood Canal Basin. Historically the Skokomish River system produced the Hood Canal region's largest runs of salmon and steelhead, most of which were produced in the North Fork Skokomish River.

The Skokomish watershed consists of three major drainages, the North Fork (33.3 miles) and South Fork Skokomish rivers (27.5 miles) and Vance Creek (11 miles). The North Fork Skokomish River originates in high mountainous areas of the Olympic National Park. Beginning in 1930, the construction of two dams as part of the Cushman hydroelectric project blocked all fish passage to the upper North Fork. The reservoirs behind the dams inundated a naturally formed lake and about 11.5 miles of the North Fork River channel and associated floodplain.

The Cushman project's lower dam diverts flow out of the watershed to a power plant on the west shore of Hood Canal. The project has reduced average annual North Fork flows below the lower dam by over 96% (Stetson Engineers 1996). This out-of-basin diversion substantially dewaters eight miles of the lower North Fork and reduces by about 40 percent, the flow of the mainstem Skokomish River. An interim instream flow of 30 cfs has been set for the North Fork Skokomish River to be released at the lower dam (WDOE, Vicki Cline, pers. comm.).

The South Fork Skokomish River originates in the Olympic National Park and flows through U.S. Forest Service (USFS) timberland and land owned by the Simpson Timber Company, before joining the North Fork to form the mainstem Skokomish River. The Skokomish mainstem then flows for about 9 miles through a wide valley to its mouth and intertidal delta on Hood Canal. Upper Vance Creek flows through USFS lands and in its middle portions through timberland owned by Simpson Timber Company. The lower 3 miles of Vance Creek is bordered by several small farms and single family homes and enters the South Fork Skokomish River at river mile 0.8. Richert Springs is a spring fed system of channels coalescing into a single channel, which enters the mainstem Skokomish at river mile 7.9. Hunter and Weaver creeks are predominately spring fed tributaries that flow through agricultural lands in the southern portion of the Skokomish floodplain and join the mainstem Skokomish River at river mile 6.2 and 4.1 respectively. Purdy Creek begins in wetlands located above the alluvial floodplain and is fed by numerous springs before joining the mainstem Skokomish River just below Weaver Creek at river mile 3.6. Fish hatcheries operated by the

Washington Department of Fish and Wildlife are located on Hunter, Weaver, and Purdy creeks where there is access to high quality spring water.

The upper portions of the South Fork and North Fork Skokomish rivers and Vance Creek are located in the Crescent Uplands, which consist of submarine basalt flows, and tuffs. Continental glaciation from British Columbia overran the lower basin and deposited hundreds of feet of sediment in the southern portion of the watershed. Soil depths are variable and generally less than 3 feet except in valley bottoms where soils are deep due to glacial deposition. River downcutting has formed steep gorges and valley walls and a broad flat alluvial valley in the lower basin, and has formed smaller gorges in the upper basin. The lower 11 miles of the watershed flow through an alluvial valley about 3/4 to 1 ½ miles wide consisting of large and small farms and numerous single family homes. The lower 5.9 miles of the river including a substantial portion of the subestuary are located on the Skokomish Indian Reservation.

The Skokomish watershed is designated as a Tier 1 Key Watershed under the President's Forest Plan (FEMAT, 1993). Industrial forestry is the dominant land use above the valley floodplain. Agriculture and residential development dominate the alluvial valley. Portions of the lower river are diked and remnants of a system of dikes and tidegates remain in the subestuary and intertidal area.

Summer Chum Distribution

Summer chum are considered extinct in the Skokomish River system and there is little population data upon which to assess potential historical distribution. However, based on observations made in a 1954-1955 study (WDF 1957) and similarities in habitat attributes between streams, it is assumed that summer chum are likely to have been distributed in the mainstem, North Fork, Vance Creek, Richert Springs, and in Hunter, Weaver, and Purdy creeks. Several thousand summer chum spawners were observed in the mainstem on October 1, 1954 (WDF 1957). Because there was no appreciable flow in the North Fork that year, owing to the Cushman hydroelectric flow diversion, no summer chum access was assumed to occur and there were no North Fork spawner surveys. Nevertheless, the habitat attributes of the North Fork suggest that summer chum may have historically ascended to the lower falls at river mile 15.6. Summer chum were observed in Purdy Creek in 1954, and while no surveys were performed in Richert Springs, Weaver Creek, or Hunter Creek, the latter streams possess habitat attributes similar to Purdy Creek and it is assumed summer chum salmon existed in them as well. Vance Creek is also assumed to have supported summer chum salmon production, due to its location, habitat characteristics and the observed early run timing of juvenile chum salmon emigrants (consistent with expected summer chum emigration timing) observed in 1955 (WDF 1957).

Population Status

Few to no summer chum salmon have been observed in spawner surveys of the Skokomish River in recent years. The stock is thought to be extirpated. A spawning ground survey in Purdy Creek conducted on September 23, 1954 documented 9 adults and 8 redds 200 yards above U.S. 101 (site of George Adams Salmon Hatchery). On October 1 of the same year an aerial survey of the Skokomish River documented over 3,000 live and dead chum from the mouth to the Hwy 101 bridge and 1,000 live and dead chum from

the bridge to the forks (WDF 1957). Observations of early returning chum have been encountered during in-river fisheries for chinook and coho and incidentally during spawning ground surveys targeting chinook since that time period, although the numbers are extremely small. In addition, a document discussing the Skokomish Indian fishery in the river presented data from 1936 through the early 1950s on catches of salmon. September counts of chum salmon were as high as 986 in 1940. Smaller catches were made during October throughout that period which may represent summer chums and early fall chums (Smoker 1952).

Factors for Decline

The Skokomish watershed has been managed primarily for timber, power production and agriculture. The habitat conditions overall are poor due primarily to water withdrawal, estuarine modifications, low channel complexity, extensive diking, sediment accumulation, peak flows, poor riparian conditions and water quality degradation. Impacts on summer chum habitat are not universal throughout the basin (different streams and stream segments are affected by varied factors for decline). For a comparison of the limiting factors in this watershed to other watersheds, refer to Part Three - section 3.4, Tables 3.17 and 3.18.

- *Low flow* - Adult migration, spawning, incubation and juvenile rearing life stages, rated high impact. From 1930 through 1988, the Cushman Project diverted all flows out of the North Fork Skokomish River at the lowermost dam, causing much of the North Fork between the lower dam and the confluence to be dry or nearly so during dry periods. This eliminated summer chum from the North Fork and severely degrading fish habitat conditions in the North Fork, mainstem Skokomish River, subestuary and intertidal delta. Since 1988, the Department of Ecology has required a minimum flow of 30 cfs [4% of average annual flow] to be released to the North Fork from the lowermost Cushman dam, pending federal licensing (WDOE 1987) . Presently with the 30cfs release, the North Fork does not meet state water quality standards due to insufficient flows for habitat and high temperatures (WDOE 1994). According to the U.S. Environmental Protection Agency, North Fork flow releases of about 228 cfs [28% of average annual flow] proposed by the Federal Energy Regulatory Commission would be inadequate for recovery of fish resources and inadequate to prevent continued impairment of fish habitat and degradation of the subestuary (EPA, 1998). The U.S. Environmental Protection Agency, U.S. Department of Commerce's National Marine Fisheries Service, and U.S. Department of Interior agree that substantial restoration of North Fork flow (target of 84% natural) is the minimum protection required for aquatic resources of the North Fork and mainstem Skokomish River and subestuary/delta (USDI, 1997; EPA, 1998; NMFS, 1998).

- *Subestuarine delta impacts* - Juvenile rearing and migration life stage, rated high impact. Probably the largest long-term impact to this delta for juvenile salmon rearing, in addition to many other ecological functions, has been the steepening of the delta and loss of approximately 17% of the delta's eelgrass habitat along the face of the delta (Jay and Simenstad, 1996). This dramatic change is primarily attributed to the loss of sediment transport through the delta due to water withdrawals by the Cushman project. Diversion of the North Fork has severely degraded estuarine habitat conditions for summer chum by disrupting sediment transport abilities and natural salinity and nutrient regimes in the subestuary and intertidal delta, and by reducing extent of tidal influence in the Skokomish River.

- *Subestuarine alterations* - Juvenile rearing and migration life stage, rated high impact. Of the original 2,175 acre delta (11.2 miles perimeter), 14.4% (313 acres) was diked for agriculture. A recent dike breach in the largest contiguous diked farm area in the delta (Nalley Farm, ~215 acres), has allowed tidal inundation of this area. Nine diked areas persist, totaling 99 acres (4.6% of original delta). Restoration of the Nalley Farm will contribute to increased juvenile summer chum rearing habitat although access is limited with the only dike breach located on the northern perimeter of the dike. Chum fry will have to migrate along existing dikes to the central portion of the delta before accessing the restoring wetland, and then predominantly at high tide. Dikes and several tidegates continue to keep wetlands isolated from the subestuary thereby cutting off the primary production in these once saltwater marshes. Two identifiable fill areas occupy approximately 5 acres (0.2% of historical delta area) of the delta and are thought to have a low impact.

- *Subestuarine road causeways* -. Thirteen roads or causeways cross or encompass the delta, the total length of which is 4.7 miles. Almost all of these roads are associated with dikes surrounding the original agricultural lands or service roads to electric line transmission towers. Even in the restoring Nalley Farm site, the dike roadways inhibit cross-delta movement of juvenile summer chum. Transmission tower service roads impact a long segment of the upper intertidal habitat, affecting tidal movement and fish foraging activity in the western portion of the delta.

- *Miscellaneous subestuarine impacts* - A debris dam and dilapidated concrete abutments are located at the junction of a major distributary channel in the delta that divides the Nalley Farm properties. The distributary once was a more prominent channel that provided access of migrating juvenile salmon to the central delta. Flow was intentionally reduced to this channel to reduce flooding potential, although some tidal flow persists (B. Martino, Skokomish Tribe Nat. Res. Dept., Potlatch, WA, pers. comm. 1998).

- *Channel complexity* - Spawning and incubation life stage, rated high impact. Historically, the Skokomish valley floodplain contained numerous sloughs, side channels and forested cedar wetlands. In the late 1800s and early 1900s woody debris and logjams were removed from the South Fork and mainstem Skokomish rivers in an attempt to prevent flooding and to facilitate log transport to saltwater via river drives. One report documented a jam 3 miles thick formed over 50 years that took 18 months to remove using dynamite, horse teams and steam donkeys (Richert, 1964). Continual channel manipulations for flood control and wood salvage have continued to the present. During the 1960s and 1970s, the WDF Stream Improvement Division removed log jams and beaver dams in Vance Creek, Purdy Creek and the North Fork Skokomish River. Despite the intense history of studies in the Skokomish basin, there is scarce instream habitat data available for the suspected summer chum reaches, although current wood loading has been characterized as poor in most channel segments (USFS 1995; Simpson Timber Co. and WDNR 1997, Skokomish DNR and PNPTC 1994). Habitat surveys conducted in 1994 in the lower 3 miles of Vance Creek found 39% pools and a range of 1.5 to 2.6 channel widths between each pool. LWD counts ranged from 0.02 to 0.15 pieces of LWD/m with much of the wood perched above the wetted perimeter, stranded on exposed gravel terraces (Skokomish DNR and PNPTC 1994). The pool data is also misleading because much of the reach was dry during the survey, skewing the number of pool habitat units due to numerous small isolated pools

(K. Dublanica, Skokomish Tribe Dept. Nat. Res., pers. comm. 1998). Observations made during a July 1998 float trip from the lower end of the South Fork Skokomish River canyon (approximately R.M. 3.0) downstream to river mile 4 on the mainstem Skokomish River (total distance of nine miles) revealed a lack of pools, long glides and riffles and a scarcity of wood, particularly large wood and jams . Ambient Monitoring has not been conducted in the North Fork Skokomish River, but observations by local biologists suggests wood loading is poor with much of it being alder and small conifer (K. Dublanica, Skokomish Tribe, personal communication 1998) The majority of the mainstem Skokomish and portions of the South Fork Skokomish River and Vance Creek have been diked and /or channelized, reducing channel complexity and sinuosity, eliminating important side channels, simplifying the remaining habitat and creating a disconnect between these streams and existing floodplain sloughs and side channels. The Highway 101 and 106 bridges over the mainstem Skokomish restrict channel migration, as do two Mason County bridges across Vance Creek. Riparian corridors in all summer chum habitat zones including the floodplain tributaries are sparse and do not provide the large woody debris necessary to maintain structurally diverse channels. Woody debris continues to be removed from the channel and riparian areas to prevent flooding and as a source of firewood and lumber. The summer chum zone is highly modified with dikes, roads and armored banks prevalent throughout the valley. Highly modified channels promote channel instability which impact summer chum by inhibiting redd construction and increasing redd scour.

- *Sediment*- Spawning and incubation life stage, rated high impact. Past timber management practices in the basin have increased sediment aggradation in Vance Creek, the South Fork and mainstem Skokomish rivers through mass wasting and road failures (USFS 1995; STC 1997). Aggradation increases flooding, scouring of redds and bed materials, bank erosion and has led to more anthropogenic channel manipulations (e.g., diking) in the valley in response to greater flooding. Bed aggradation and channel braiding in the valley is well documented and is attributable to 1) increased sediment from road and slope failures due to logging, 2) reductions in sediment transport abilities with loss of flows from the North Fork Skokomish, 3) dikes limiting transport of bed materials out of the channel and onto floodplain areas and cutting off side channels and sloughs and 4) loss of stable bars and banks throughout the basin due to reductions in instream woody debris and riparian forests. Aggradation has reduced the conveyance capacity of the mainstem from the pre-Cushman level of 18,000 cfs to roughly 5,000 cfs (Stetson, 1996). Aggradation has been estimated by numerous entities to range from 3.0 to 4.5 feet (USDI 1997). Aggraded channels tend to be unstable with severe scour and fill episodes following storm events which destroy redds and hinder redd construction.

- *Peak flows* - Incubation life stage, rated high impact. Timber management has increased fall/winter storm flows by broadening the hydrograph and increasing the duration of high flows by up to 18%. These changes could translate to increases in sediment transport and channel disturbance (Simpson Timber Co. and WDNR 1997), scouring the redd environment. Road densities in some sub-basins in the South Fork Skokomish and Vance Creek drainages are over 6 miles/mile sq. and may contribute to peak flows by extending the stream network. Rain on snow peak flow events, combined with an aggrading channel, affects the incubation environment by bed scour and movement. Dikes contribute to bed scour by retaining water within the channel forcing the energy down onto the substrate rather than laterally across the floodplain. Typically depth of scour is greater in diked reaches than undiked

reaches. Dikes and removal and filling of important side channel habitats eliminated these areas from floodwater retention.

- *Riparian condition* - Spawning and incubation life stage, rated high impact. Riparian and floodplain habitat was removed in the late 1800s and early 1900s as the thick old growth stands in the lower valley were cleared for farming, timber extraction and perceived flood protection (Richert, 1964). A large portion of the valley is maintained in agricultural fields. Sixty two percent of the mainstem Skokomish River, 81% of Hunter Creek, and 57% of Weaver Creek are either agricultural fields, sparsely vegetated, and/or have a forested riparian buffer <66 feet in width. The South Fork and Vance Creek riparian forests are in slightly better condition overall with 20% and 32% respectively as sparsely vegetated or <66 feet in width. The North Fork Skokomish and Richert Springs are the least disturbed with less than 20% of the riparian forest sparsely vegetated or with widths <66 feet in width (PNPTC, 1998). The majority of Purdy Creek flows through a large intact wetland system, except for the hatchery area above Hwy 101 which is the location of summer chum observations in 1954. Degraded or non-existent riparian forests affect potential recruitment of LWD to stream channels. Lack of instream and potential sources of woody debris leads to reduced pool habitat, increased bank erosion, unstable bars and stream channels thereby affecting the spawning and incubation environment.

- *Water quality (temperature, nutrients)* - Adult migration, spawning and rearing life stages, rated low impact. Elevated summer temperatures have been observed in the SF Skokomish River partially attributable to channel widening and aggradation which can inhibit upstream movement and migration of summer chum and induce premature emigration of fry from the redd environment (K. Dublanica, personal communication, 1998). Elevated temperatures may occur in the mainstem as well where water withdrawal along with aggradation and channel widening could influence peak temperatures. Nutrients from livestock and septic systems may impact water quality in the river and subestuary causing shifts in primary and secondary production of marine organisms. Failing septic systems and livestock are thought to be responsible for high levels of fecal coliform noted in several tributaries including Purdy,Weaver, Hunter creeks and parts of the mainstem (J. Park, Skokomish DNR, pers. comm. 1998).

Factors for Recovery

In general, to assist in restoring summer chum habitat in the Skokomish watershed it is necessary to restrict development in critical reaches of the Skokomish Valley. Additionally, the following actions should be taken: 1) protect and restore the existing riparian and wetland habitats in the basin to enhance instream woody debris inputs, moderate temperatures and promote aquatic habitat diversity; 2) encourage the maximum amount of the watershed to be maintained as forestland; 3) restore floodplain connections of wetlands, sloughs and side channels with the main river channel; 4) reduce sediment inputs by road stabilization or abandonment, avoid timber harvests on unstable slopes; 5) restore riparian forests; 6) return flows to the North Fork to reduce bed aggradation in the mainstem Skokomish and return sediment transport to the delta, including reversal of eelgrass habitat loss in outer delta (additionally, it will restore mainstem channel depth and conveyance capacity as mandated by the Department of the Interior and recommended by the National Marine Fisheries Service, Skokomish Tribe, Pacific Fisheries Management Council, Hood

Canal Coordinating Council, Mason County and others (USDI 1997)); and 7) restore and enhance subestuary habitat through modification of dikes and tidegates. The following are more detailed descriptions of factors needed for recovery.

- *Water withdrawal* - The Department of the Interior's mandatory conditions for future operation of the Cushman Project, which include managed restoration of North Fork flow and restoration of mainstem channel conveyance capacity, represent the minimum requirements for protection and restoration of anadromous fish in the Skokomish River system and subestuary, and are broadly supported by federal, regional and local resource agencies and comprehensive watershed planning led by the Skokomish Tribe. Substantial restoration of North Fork flow from the Cushman Project is essential to reduce or eliminate aggradation of the mainstem channel, enhance instream habitat conditions and reverse continuing degradation of critical estuarine habitat. In addition, restored flows during the summer low flow months would improve upstream migration of all salmonids including summer chum and promote the recovery of the North Fork Skokomish River channel. The DOI/NMFS/EPA agreement on Interior 4(e) flow restoration conditions, are the minimum necessary to protect aquatic resources.

- *Subestuarine alterations* - Restore subestuary migration and rearing habitat by eliminating dikes, tide gates and roadways, converting agricultural lands back to estuarine wetlands and natural distributary and dendritic channels. Restoration of flows from the Cushman project is essential for subestuary recovery (Jay and Simenstad 1996). Several reports have been commissioned by the Skokomish Tribe to examine the structure of the delta and the potential for restoration, including environmental impacts and cost estimates for dike breaching (USCOE 1995).

- *Channel complexity/ aggradation* - There have been several areas identified by the Mason County Department of Public Works where the potential for catastrophic channel avulsions may occur due to sediment aggradation and confinement by dikes. These reaches as well as others are extremely dynamic. Removal of dikes and property buy-outs and/or purchase of floodplain easements from willing landowners would allow the river to migrate and interact with its floodplain. Allowing the channel to migrate in these dynamic reaches will over time decrease stream power by increasing channel sinuosity, increase available habitat and reduce bed aggradation. Reconnection of isolated sloughs and side channels will increase habitat diversity and promote habitat development. In addition, in conjunction with restoration of North Fork flows from the Cushman project, there may be a need for mechanical removal of sediments in selected reaches of the river. However, on it's own, mechanical removal of sediment would not be cost effective or achieve the desired outcome of restoring channel capacity and natural stream function. Instream habitat may be protected and enhanced by experimenting with and monitoring the use of engineered logjams (ELJ's) to stabilize bars and reduce erosion potential.

- *Peak flows* - At a landscape level it is necessary to restore ecosystem processes and lessen peak flow impacts by reducing road densities through obliteration and decommissioning, and improving the remaining road drainage network by installing larger and more frequent cross drains and water bars. The forest must be allowed to mature to improve hydrologic maturity and to reduce rain on snow

impacts. The forest stand age can be increased throughout the watershed by staggering harvest units and reducing even age (clear-cut) harvests.

- *Riparian condition* - The riparian corridors in all summer chum habitats in the Skokomish Valley need to be enhanced through revegetation efforts. Dike decommissioning and subsequent revegetation efforts along the mainstem streams will allow the river to migrate, connecting the river with its floodplain and incorporate riparian vegetation into the stream channels. Much of the adjacent agricultural lands (especially Hunter and Weaver creeks) need to be enhanced by revegetation and fencing with livestock exclusion fencing. Riparian corridors need to be significantly wider and allow for the natural movement of the alluvial river segments in their floodplain. Water quality will be enhanced as well with the addition of wider riparian areas and fencing which will assist in moderating temperature impacts and preventing livestock access to the streams. A riparian forest protection/restoration plan may assist in developing these riparian corridors and would be greatly enhanced by support from local citizens. Riparian corridors above the summer chum zone in Vance Creek, South and North Fork Skokomish rivers provide LWD to downstream reaches and need protection as well. Simpson Timber Company has proposed a 50 year timber management plan for their lands in the Skokomish basin (Simpson Timber Company 1998), but the adequacy of protections have not been evaluated completely.

Strength of Evaluation and Information Needs

Numerous studies, reports and documents have been drafted discussing various issues in the Skokomish watershed. The major plans include a DNR/Simpson Timber Co. watershed analysis on the South Fork Skokomish River (Simpson Timber Co. and WDNR 1997) to direct watershed protection and identify sensitive habitats, a Draft Habitat Conservation Plan/Landscape Plan proposed by Simpson Timber Company, the Presidents Forest Plan (1994) and a federal watershed analysis of the South Fork Skokomish River (USFS 1995) to guide USFS land management and restoration efforts, a KCM Consultants (1997) to reduce the impact of flooding on people and property and finally the Skokomish Tribe's Watershed/Ecosystem Improvement Action Plan (in press). Numerous other documents are available as well including historical information on Skokomish valley settlement and activities (Richert, 1964). Impacts to the aquatic system are well documented and the confidence in the habitat factors for decline is high but the confidence in the escapement and distribution of summer chum in the watershed is low to moderate.

More information is needed to determine current summer chum use and to assess the relative impacts of land use on summer chum habitat. Information needs include:

1. Monitoring of bed scour in selected channel reaches correlated to flows from existing USGS gauges or other means of measuring flows.
2. Monitoring habitat components in the subestuary as agricultural lands are converted back to subestuary habitats.
3. Dike reconnaissance throughout the basin to identify dikes structural integrity and dikes that have major negative influences on channel geometry.

4. Increase survey effort throughout the Skokomish and tributaries to document any current summer chum utilization in the basin.
5. Investigate modification of the log jam at the top of Nalley slough to facilitate the movement of juvenile and adult salmon as well as sediment and flow.

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Union Watershed Narrative
WRIA 15.0503

Watershed Description

The Union River enters Lynch Cove in the eastern arm of Hood Canal**.** The watershed area is approximately 24 square miles with 10 miles of mainstem and 30 miles of tributary streams. The headwaters are in the Blue Hills near 1,500 ft. elevation and flow through an undeveloped watershed before entering the Union River Reservoir constructed in 1955-57 as a municipal and industrial water supply. It provides up to 5 million gallons/day for the City of Bremerton and the Puget Sound Naval Shipyard (Williams et al. 1975). The upper watershed contains moderate to steep side-slopes with a relatively low gradient stream channel downstream to McKenna Falls located at river mile (RM) 6.7 immediately below the water supply dam (Cascade Dam) and reservoir. Below the falls, the gradient is also low with the lower 5 miles being quite flat and flowing through a broad shrub-scrub floodplain. The Union River enters a subestuarine delta that has been heavily constrained by diking and filling, mainly for agriculture, flood control, and to protect residences located in the subestuary. The Washington Department of Ecology has closed the Union River and its tributaries from the mouth upstream to McKenna Falls to surface water appropriations (WDOE, 1998).

The dominant landuse in the upper portions of the Union River and its tributaries is industrial forestry and water storage/diversion. The middle and lower reaches have moderately heavy residential development as well as numerous small hobby farms and minor forestry operations (Williams et al. 1975; PSCRBT, 1991). The City of Belfair is located directly east of the river mouth and subestuary. Three county owned bridge crossings and several privately owned bridges (some of poor design) (J. Lenzi, WDFW, Olympia, WA pers. comm.) exist which prevent the river from migrating throughout its floodplain.

Summer Chum Distribution

Current summer chum distribution is primarily limited to the lower 2.5 miles, but extends upstream as well. Historical distribution is assumed to have extended to the base of McKenna Falls (RM 6.7) under historical flow conditions. Several small tributaries exist within this reach, including Courtney, Bear and Hazel creeks and the East Fork Union River, however historical use by summer chum salmon is unknown.

Population Status

Escapement estimates show 100 or less spawners during the 1970s. Since then, escapement has risen to several hundred most years with a high of almost 1,900 spawners in 1986. This population contrasts with the rest of the Hood Canal/Strait of Juan de Fuca summer chum populations in that the abundance of the stock has increased since 1978 (Appendix Table 1.1). Although the stock has experienced a general increase over the last 15 years, it is still thought to be less than the historical run size.

Factors for Decline

The Union River watershed is dominated by residential development, small farms, and industrial forestry. The freshwater habitat overall is in fair condition with the majority of the impacts occurring from encroachment by homes and farms in the floodplain and dikes and agricultural activities and modifications in the subestuary and intertidal areas. The Union River is the only basin on the Kitsap Peninsula to possess a viable population of summer chum salmon. The potential for further habitat degradation remains high due to the trends in growth, urban landuse designations and inadequate stream, riparian and shoreline protections. For a comparison of the limiting factors in this watershed to other watersheds, refer to Part Three - section 3.4, Tables 3.17 and 3.18.

- *Subestuarine habitat loss and degradation* - Juvenile rearing and migration life stage, rated high impact. For it's comparatively small size of 344.6 acres (6.1 miles perimeter), the estuarine delta of the Union River has been extensively diked and the tidal floodplain constrained as a result. Seven diked areas occupy 78.6 acres or 22.8% of the original summer chum rearing and migration habitat area. Some of these diked areas may be breached and now inundated by the tide but the extent of restoration to tidal circulation and the state of recovery cannot be verified without ground truthing. Several tidegates have been identified but their condition and impact on summer chum estuarine habitat is unknown (M. Schirato, WDFW, Olympia, WA pers. comm., Oct. 1995). Juvenile summer chum rearing opportunities are presently limited compared to the historic state of the subestuary. In particular, habitat extent and quality in the mesohaline reaches of the subestuary, which chum fry may volitionally occupy for up to 1-2 weeks, are very limited due to the diking. Much of the breaching of marshes appears to be in an early state of restoration. Fills for commercial or residential use include two areas totaling 3.6 acres, approximately 8.9% of the historical delta area. At least one of these fills is located on the outer edge of the historic subestuary, thus imposing an intertidal barrier to migrating summer chum fry. One small (0.9 acres) pond or other excavation is evident within the delta but its impact is thought to be minor.

- *Subestuarine ditches and remnant dikes* - Juvenile rearing and migration life stage, rated high impact. Although much of the historically diked delta habitat in the Union River subestuary is now exposed to renewed tidal inundation, the associated ditching that accompanied diking and agricultural activities have heavily modified emergent marsh and other intertidal habitats. While these ditches and remnant dikes may not impose a direct impact, they likely inhibit restoration of natural drainage channel systems and delay long-term recovery of estuarine rearing habitat for summer chum. At least 19 ditch and remnant dikes are present, and extend over approximately 2 miles of delta habitat. Many of these are concentrated in a large dike-breach marsh in the lower extent of the delta, where chum fry would be expected to "stage" for migration into the Canal. Such ditching typically prevents or delays the formation of natural dendritic tidal channel systems, which in turn impacts foraging opportunities for juvenile salmon in the marshes. In addition, prey resources of the emergent marshes, which can be important to chum fry early in the estuarine migration, are likely progressing at a slower recovery rate than natural because of the ditching.

- *Riparian condition* - Spawning and incubation life stages, rated high impact. Most of the basin was completely logged of the original forests by the 1930s (Amato 1996). Numerous farms, residential

developments and associated bank armoring exist in the riparian corridor affecting the functional status of the riparian forest. Currently fifty two percent of the riparian area is forested of which 96% is dominated by deciduous trees. Sixty two percent of the total riparian length is sparsely vegetated or less than 66 feet wide (Appendix Report 3.7). Rural residential development, agriculture, and roads cover 46% of the riparian area. A more mature and diverse riparian forest is likely to provide stable LWD to create structurally diverse channel conditions and improve stream habitat overall.

- *Channel complexity* - Spawning and incubation life stages, rated moderate impact. The Union River still possesses a structurally diverse channel network with 63% pools. However pool frequency is poor at 5.9 channel widths between each pool. The stream contains low levels of large size LWD due to past stream clean-outs, riparian forest harvesting and natural transport downstream. Habitat surveys in 1993 found the Union River averaged 0.22 pieces of LWD/m from the mouth to McKenna Falls with nearly 42% of the wood being in the small size class [10-20 cm diameter] (PNPTC, 1995, Appendix Report 3.8). The low levels of large size instream LWD may result in redd scour and channel instability. Much of the current instream LWD is western red cedar, which has long instream residency times due to its slow rate of decay. Stream clean-outs of LWD, particularly log jams and channelizations have been recorded back to the late 1800s but were more extensive during the late 1960s. For instance in 1967 the WDF stream improvement division noted that five log jams were removed from the Union River and it was channelized for 5 miles. In a three year period in the late 1960s, numerous log jams were removed from the Union River and 2 of the larger tributaries, Courtney Creek and Bear Creek. In addition, rip rap was placed along 2 miles of Courtney Creek in 2 consecutive years in 1967 and 1968 and the lower two miles of Courtney Creek appears to have been moved sometime in the distant past (Amato, 1996). The previous channel alignment still exists on maps in existence today including the 7.5 minute U.S.G.S. Belfair Quadrangle map printed in 1994.

- *Low flow* - Adult migration and spawning life stage, rated low impact. The impact of water withdrawal by the City of Bremerton is thought to have a low impact on Union River summer chum salmon, but the actual impacts are unknown. Based on 1998 flow data, outflow from the Union Reservoir exceeded inflow to the reservoir during the critical migration and spawning period of mid-August to mid-October 73% of the time (43 of 59 days) (City of Bremerton 1998). Preceding years have not been assessed at this time. Out of basin diversion may reduce the amount of water available for summer chum migration and spawning from historical conditions and may reduce the amount of spawning area available to adults at the site and reach scale, including adequate access to upstream reaches and tributary streams. Mean annual flow for the Union River for the period of 1947 - 1959 was 54.7 cfs with a mean annual minimum flow of 42.7 and a 1 day low flow of 14 cfs. The Bremerton Water Utility maintains a continuous flow gaging station downstream of the dam which has operated from 1958 to the present, however no summary of flow data was available for this station (PSCRBT 1991). An administrative low flow has been set at 3 cfs for the Union River below McKenna Falls and 10 cfs at the river mouth (Cline 1998).

- *Water quality (toxics, nutrients, temperature)* - Adult migration, spawning and rearing life stages, rated low impact. Toxic chemicals (mercury, selenium, cadmium, arsenic, boron) have been found in sediment and water samples near the vicinity of the Olympic View Sanitary Landfill located near the East Fork Union River confluence. Although the impact on summer chum is thought to be low, there

has not been any analysis of the impacts. Additionally, the Lynch Cove subestuary at the mouth of the Union River had the highest levels of cadmium and arsenic found in Puget Sound and the third highest levels of chromium and copper (documented by the Puget Sound Ambient Monitoring Program in a letter to DOE from the Mason County Commissioners 1994). Sediment laden, petroleum smelling effluent at approximately RM 6 has been noted near a commercial paving company, but like the toxics mentioned above, the impacts are unknown. Livestock have direct access to the stream in several locations and may inhibit redd formation by creating unstable conditions in the immediate area. Nutrients from livestock and septic systems may impact water quality in the river and subestuary, causing shifts in primary and secondary production. Past water sampling has revealed high bacterial counts in the lower section of the river apparently attributable to septic systems and stormwater (PSCRBT 1991). Summer temperatures may be elevated due to water withdrawals and the lack of riparian shading which can inhibit the upstream movement and migration of summer chum and induce premature immigration of fry from the redd environment increasing mortality

Factors for Recovery

A general discussion of restoration and protection options for these habitat factors is found in Part Three - section 3.4.4.2, toolkit.

- *Subestuarine habitat* - Currently, Belfair and much of the watershed is designated as an urban growth area in the Mason County Comprehensive Plan and the Union River and most of the nearshore marine areas in Hood Canal adjacent to the Union River have an urban designation under the Mason County Shoreline Master Program. There is a need to strengthen the protection strategies for buffers, building setbacks and bulkhead constructions. The county and other entities should consider acquiring undeveloped estuarine and marine shorelines for permanent protection or acquiring conservation easements from willing landowners. Both existing diked and breached-dike estuarine wetlands are likely limiting the potential for maximal rearing of summer chum within the estuarine delta. Restoration action in the form of dike breaching, with setback dikes to protect public and private property from flood damage if necessary, and ditch in-filling should be considered as the most proactive approaches to recovering critical summer chum habitat in this subestuary. There is a need to evaluate the effectiveness of dikes and the relative impacts on the tidal/freshwater environments and, if appropriate, negotiate restoration opportunities with the landowners.

- *Riparian condition and LWD* - Enhance existing riparian forests through underplanting of shade tolerant conifer and encourage riparian planting throughout the riparian corridor. Consider acquisition of sensitive properties or conservation easements from willing property owners. Modify local government (county and state) riparian protection strategies to protect stream and riparian areas from further residential development.

- *Channel complexity* - Allow natural LWD input processes to occur and LWD to remain in the channel, and consider developing restoration projects to deliver additional wood to the channel. Enhance and restore degraded riparian areas through local partnerships.

- *Water quality* - Elevate best management practices (BMPs) utilized by industrial landowners, small farms and residential homeowners to reduce impacts on instream habitat and water quality. Increase riparian protections through local and state ordinances and laws. Enact effective stormwater protections to reduce the impact of future projected growth on basin hydrology and water quality.

- *Increase awareness and education* - Work with local groups (Union River Basin Protection Association, Hood Canal Salmon Enhancement Group, Theler Wetland Project Center) and stakeholders to increase environmental awareness and educate the public about the importance of functional habitats to preserve and protect all salmon stocks.

Strength of Evaluation and Information Needs

Confidence in this assessment is rated as moderate due to the amount of information available for analysis, including TFW instream ambient monitoring data, escapement/survey data, historical research conducted by PNPTC and knowledge of experienced habitat biologists in the area.

More information is needed to assess the relative impacts in the summer chum habitat zone.
Information needs include:

1. Assess and quantify the impacts from dikes located in the subestuary on summer chum salmon populations and potential for restoration.
2. Evaluate the recovery of vegetation communities and critical prey resources in the subestuary and intertidal areas.
3. Identify impacts from current water withdrawals by the City of Bremerton and possible measures to improve conditions if warranted.
4. Water quality monitoring (toxics, nutrients, temperature) at industrial sites and throughout the summer chum habitat zone.
5. Continued stream channel habitat monitoring to determine habitat trends.
6. Monitoring of bed scour in selected reaches associated with instream flow measurements.
7. Increased survey effort to document summer chum utilization above the current index area at river mile 2.1 and in the various lower tributaries.

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Big Mission Watershed Narrative
WRIA 15.0495

Watershed Description

The Big Mission Creek watershed enters the eastern arm of Hood Canal and Lynch Cove at Plum Point approximately 2 miles west of the Union River and 3 miles west of the city of Belfair. It contains nearly 10 miles of mainstem and 10 miles of tributary streams. The mean annual flow for Big Mission Creek measured at river mile 4.8 from 1946 to 1953 was 12.4 cfs, with a mean annual minimum flow of 8.5 cfs and a peak flow of 403 cfs (PSCRBT, 1991). The Washington Department of Ecology has closed Big Mission Creek, Mission Lake and their tributaries to further surface water appropriations (WDOE, 1998).

The headwaters begin in a forested area above Mission Lake and in wetlands northwest of Mission Lake, which coalesce into a single stream immediately downstream of Mission Lake outlet. Channel gradients are typically less than five percent the entire length of the creek and flow through glacial advance and recessional outwash sediments consisting of unconsolidated silt, and gravel, which is highly erodible (PSCRBT, 1991). The upper and middle portions of the watershed are forested and dominated by industrial forests managed by the Washington Department of Natural Resources and other industrial forestland owners. The lower 2 miles has several county road crossings and a nearly continuous corridor of single family residences located in the riparian zone. The lower 1/10th mile flows through Belfair State Park and into Hood Canal via a heavily modified and constricted estuarine delta. Analysis of a 1944 aerial photo indicates the subestuarine delta (which is now part of Belfair State Park) was diked and used as a farm at that time. Diking and other modifications have caused a significant loss in estuarine rearing and physiological transition habitat for chum salmon.

Summer Chum Distribution

Spawning ground surveys since 1974 show only a fall chum population in this watershed. This watershed is included in this plan based on the historical potential for summer chum utilization given available suitable habitat, stable late summer flows, and proximity to the Union River, which supports summer chum. Based on the presence of suitable habitat, summer chum could range up to RM 1.5.

Population Status

Spawning survey data indicate that a summer chum population does not exist at this time (WDFW 1998). However habitat and flow conditions appear conducive to summer chum and it is possible that prior to spawning surveys (1974), summer chum did exist in this watershed.

Factors for Decline

The potential summer chum habitat zone in the lower 2 miles of the watershed is in poor condition when compared with the upstream forested areas, primarily due to residential development, road crossings, stream

modifications and timber harvesting. For summary results of the limiting factor analysis, refer to Part Three - section 3.4, Tables 3.17 and 3.18.

- *Subestuarine habitat loss*- Juvenile rearing and adult migration/spawning stages, rated high impact. The historical area of this small delta is estimated to be 30.3 acres. Two diked areas comprise 10.3 acres or 34% of the original intertidal habitat potentially available for chum salmon. One large diked area also contains a man-made pond. This extensive diking has likely caused the expansion of the delta into the Canal, although the extent of this has not been estimated to our knowledge. The mesohaline reach of the subestuary is heavily constrained by dikes with minimal emergent or other wetland vegetation. The dikes have resulted in a significant direct loss of habitat and have altered the natural process of tidal mixing in the tidal/freshwater zone which is an important zone for feeding success and transition area from freshwater to saltwater life stages. Two remnant ditches and dikes extend 0.14 miles within the delta, but their impact is unknown and thought to be relatively small.

- *Riparian landuse*- Spawning and incubation life stages, rated high impact. Seventy percent of the riparian area in the potential summer chum reach is forested with 36% being <12 inches dbh (diameter breast height) and 98% dominated by deciduous trees. Forty five percent of the linear buffer length is sparsely vegetated or is less than 66 feet wide. Residential/commercial development and roads cover 30% of the total buffer area, which has reduced the extent of a functional riparian forest (PNPTC 1998, Appendix Report 3.7). The current riparian forest is unable to provide LWD (large woody debris) needed for the creation of stable instream habitat, which impacts the spawning success of chum salmon.

- *Channel complexity*-Spawning and incubation life stages, rated high impact. Habitat surveys conducted in Big Mission Creek revealed 33% pools, 0.07 pieces of LWD/m., and an average of 6.5 channel widths between each pool within the potential summer chum reach (Appendix Report 3.7). This compares to 43% pools and slightly higher wood frequencies and lower pool spacing in the forested area upstream (PNPTC 1995). Bank armoring, removal of standing trees recruitable as LWD and removal of instream large woody debris all continue in association with existing residential development adjacent to the stream channel. A stream channel lacking diverse structure leads to increased redd scour and poorly sorted spawning gravels, which may inhibit redd formation. In the mid to late 1960s WDF stream cleaning crews removed log jams from 12 miles of the watershed and channelized the stream for 4 miles over a four year period in an attempt to improve upstream migration of fish (Amato, 1996). This work presumably included portions of the summer chum zone. In addition, the channel entering the delta may have been channelized to some extent as well. The impacts of low channel complexity are believed to exert a high impact.

Factors for Recovery

A full discussion of protection options and restoration stategies by habitat factor is found in Part Three - section 3.4.4.2, toolkit.

- *Subestuarine habitat* - Summer chum essentially have little or no brackish to mesohaline rearing habitat in the Big Mission subestuary due to diking and other development of the historic delta. Removal and

setback of dikes could contribute significantly to the recovery of a natural distributary tidal channel system and estuarine wetland communities that would significantly enhance rearing prior to migration into the adjacent Canal. Removal of unnecessary fills and bulkheads will allow natural shoreline processes to occur. Property buy outs or conservation easements may be appropriate for some critical areas. Consider negotiating with Belfair State Park and the Washington Parks Department to reconfigure lower stream channel if it is thought that the results would be favorable to summer chum salmon. Strengthen local governments' protection strategies for riparian protections, building setbacks, storm-water runoff and shoreline armoring.

- *Riparian condition and LWD* - Enhance existing riparian corridors through underplanting of shade tolerant conifer. Consider acquisition of sensitive properties or conservation easements of developed properties that can be enhanced. Modify local governments' riparian protection strategies to protect the stream and riparian areas from further residential development by requiring functional riparian buffers. In the middle portion of the watershed the Washington Department of Natural Resources has developed a long term Habitat Conservation Plan for industrial forest activities on state land which will provide increased riparian protections during timber harvesting, but the adequacy of protections have not been evaluated completely. Nevertheless, it will be desirable to link the DNR riparian forests with the riparian corridors in the lower summer chum zone.

- *Channel complexity* - Allow natural woody debris input processes to occur and consider developing restoration projects to deliver additional wood to the channel. Remove unnecessary rip rap and restore sites with appropriate bioengineered techniques. Evaluate the effectiveness of culverts/bridges to allow the free movement of wood, water and sediment to downstream reaches.

- *Increase awareness and education* - Work with local groups and stakeholders to increase environmental awareness and importance of functional habitat to preserve all salmon stocks. Develop local watershed groups to assist in monitoring environmental conditions.

Strength of Evaluation and Information needs

Confidence for fish distribution is rated low, and based upon professional judgement of where summer chum would likely spawn. Confidence in the habitat assessment is high due to the TFW ambient monitoring data, historical overview, PNPTC riparian assessment and the field knowledge of several local biologists.

More information is needed to assess the relative impacts of land use on summer chum habitat. Information needs include:

1. Water quality monitoring throughout the summer chum habitat zone.
2. Monitoring of bed scour in selected reaches associated with stream flow data and channel cross sections.
3. Increase in survey effort during the summer chum entry period in an attempt to document any current use by summer chum salmon beyond the current survey reach.
4. Analysis of the impact on freshwater and estuarine habitat created by the Belfair State Park and potential for restoration of this critical zone.

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Tahuya Watershed Narrative
WRIA 15.0446

Watershed Description

The Tahuya River is the largest stream draining Kitsap Peninsula at 45.1 sq. miles, and is located east of Rendsland Creek and the Dewatto River, south of Big Beef Creek, and west of Big Mission Creek and the Union River. It headwaters in the Green Mountain on the plateau of the Kitsap peninsula and flows southwesterly entering the east side of Hood Canal at the community of Tahuya. The Tahuya River has a total mainstem length of 21 miles and a combined tributary length of approximately 64.9 miles.

Below Lake Tahuya, the Tahuya River flows through gently rolling hills with a low to moderate stream gradient. Below RM 14, the river flows through a broad alluvial valley. A distinctive feature of the Tahuya River and most of the streams draining southwest Kitsap Peninsula is the large wetland sections directly associated with the mainstem and numerous tributary wetlands within the drainage. The geology of this watershed is dominated by glacial till. The moderate terrain and low elevation of the Tahuya River watershed results in a rain dominated hydrologic pattern where many of the smaller tributaries go dry early in the summer season, or during winter dry periods. The numerous wetlands within the watershed are critical in moderating peak winter flow and augmenting summer low flow. To provide instream flows during the summer low flow period, the Department of Ecology has closed the Tahuya River to additional consumptive appropriations during the time period June 15 to October 15, per WAC 173-515-040(2).

The primary historical land use in this watershed was timber harvest. A large portion of the watershed is still managed for timber in the Washington Department of Natural Resources, Tahuya State Forest, and on the lands of private timber companies. Seventy one percent of the riparian zone is fully forested, with another 6% clearcut. Agricultural accounts for 8% of the riparian zone, mainly in the form of Christmas tree and small farms. Residential neighborhoods within the 100-year floodplain account for another 12% of the riparian zone. The immediate shoreline of Hood Canal is intensely developed. Many of the natural lakes, reservoirs, and wetlands in the Tahuya drainage are also intensely developed.

Summer Chum Distribution

Past spawning surveys found summer chum below RM (river mile) 3.0. However, given present flow and gradient patterns, summer chum could extend up to RM 8.0.

Population Status

During the early 1970s estimated escapement ranged from the high hundreds to thousands. By the 1980s, it was reduced to less than 200. Summer chum have been detected at very low numbers since the early 1990s (Appendix Table 1.1), and a viable population no longer exists.

Factors for Decline

Aerial photo analysis shows that the lower river channel from RM 0.0 to 3.0, where historically most of the summer chum spawned, has approximately 50 percent of the channel length impacted (on at least one riverbank) by roads, agriculture, and residential development. The adjacent nearshore and estuary habitat has been intensely developed. The habitat is degraded due to (in order of importance): nearshore habitat loss, loss of LWD, the loss of species diversity within the riparian forest, elevated water temperatures late in the summer season, and channel instability. As pressure to develop shoreline and floodplain increases, there is increasing conflict between natural shoreline and channel processes that maintain habitat and bank armoring, flood protection, and LWD removal. For a comparison of the limiting factors in this watershed to other watersheds, refer to Part Three - section 3.4, Tables 3.17 and 3.18.

- *Nearshore habitat loss*- Early rearing life stage, rated high impact. Nearshore development including, bulkheads, filling of near shore areas, erosion onto beaches, installation of docks, and loss of shoreline vegetation, has reduced and eliminated nearshore habitat. Bulkheads increase the rate of beach erosion, modifying and eliminating suitable habitat. Bulkheads and docks force fish into deeper water where they are subjected to increased predation by birds and other fish species. Installation of bulkheads reduces available habitat for chum prey. Bulkheads and filling of nearshore habitat eliminates eelgrass beds and salt marsh, important rearing and feeding habitats. Removal of shoreline vegetation reduces shade, shoreline LWD, and increases erosion onto beaches, all important factors in the survival of summer chum and their prey. Shoreline vegetation is also an important source of terrestrial chum prey. Dock installation through filling, shading, and physical disturbance of the beach eliminates eelgrass beds, micro and macro algae, disrupts salmon migration, increases predation by forcing salmon into deep water, displaces prey species, and disrupts beach spawning of prey species.

- *Water quality, temperature*-Adult spawning life history stage, rated high impact. High water temperatures into late September can negatively affect summer chum by preventing the entry of adults into the river, exposing them to predation. Temperature data shows that on some years water temperatures are 12 degrees Celsius or higher through the first half of September (PNPTC 1994, 1995, 1996, 1997). Reductions in the extent of riparian forests, and the size of trees within the riparian forest increase stream temperatures through a loss of shade and transpiration. Within the lower 9 miles of the Tahuya River 29% of the riparian forest is less than 66 feet in width or sparsely vegetated (Appendix Report 3.7).

- *Riparian forest condition*-Spawning and incubation life history stages, rated moderate impact. By 1930 most of the old growth in the Tahuya River watershed had been harvested (Amato 1996). Historical riparian forests were dominated by a mixture of old growth western red cedar, Douglas-fir, western hemlock, and areas of younger alder. Stumps remaining in the riparian forest adjacent to the stream channel network show that in most areas all the large conifer trees available for recruitment into the stream channel were removed with timber harvest. Presently, 7% of the riparian zone (by stream length) has no buffer, 24% averages <12 in. dbh and, 69% is 12 to 20 inches dbh (12-20 in dbh). Species composition of riparian forest is 52% deciduous dominated, and 37% mixed conifer and deciduous. Forty four percent of the riparian forest is greater than 132 feet in width, 27% 66 to 132 feet in width,

and 29% less than 66 feet in width and/or sparsely vegetated. Riparian land use within the riparian buffer is 71% forested, 12% rural residential and 8% agriculture (Appendix Report 3.7). Although 44% of the riparian forest greater than 132 feet in width and 71% of the riparian buffer forested, the small size of most of the trees and lack of conifer in the riparian forest combine for a moderate impact. The habitat is in recovery, however development of this watershed is expected to rapidly increase over the coming decades. Habitat surveys (between RM 4.0 and 9.0) of the Tahuya mainstem shows low numbers of LWD at 0.15 pcs/m of channel length (Appendix Report 3.8). Levels of LWD will continue to decline for the next 25 to 50 years until the existing riparian forest to matures and contributes large diameter LWD to the stream channel.

- *Channel complexity*-Spawning and incubation life history stages, rated moderate impact. Road building, diking, channelization, floodplain agriculture and residences, and bank armoring have constricted the floodplain and limited channel movement and the creation of new habitat. Agriculture landuse found on the floodplain at RM 0.5 to 0.8 and RM 1.1 to 1.3 has eliminated or limited riparian forest development. From RM 1.6 to 2.0, a farm is located on a floodplain island bounded by the mainstem and a side-channel of the river. A roughly 800 foot long dike protects this site. Residential development at RM 2.5 to 2.7 is located in the floodplain on the west side of the river. Residential development at RM 4.5 to 6.0 is located in the floodplain on the north side of the river. Agriculture and residential developments also occur from RM 6.0 to 6.2. From RM 6.3 to 6.9 homes are placed directly on the river bank, and agricultural developments is cutting off old river meanders. Fill is used to protect residential development at RM 7.3 to 7.6. The residential and agricultural development in the floodplain and riparian forest of the river has resulted in the removal of riparian vegetation and bank armoring from river mile 7.5 downstream.

  From 1955 to 1970, the Washington Department of Fisheries Stream Improvement Division removed what was considered at that time as blockages to upstream salmon migration. Logjams, debris, and beaver dams were removed and many miles of mainstem and tributaries were channelized (Amato 1996). The result was a loss of channel complexity and bed stability. From habitat survey data, the Tahuya River has 72% pools, 0.15 pieces of LWD/meter, and an average of 2.4 channel widths between each pool (Appendix Report 3.8). This is a low impact for percent pool, a high impact for LWD and a moderate impact for pool spacing. The low density of LWD has not translated into a low percent pools, since LWD is not the only pool forming factor in low gradient, wetland dominated, channels such as the Tahuya. The combined ratings for channel complexity are rated as moderate, however conditions may decline for the next 50 to 100 years until the existing riparian forest matures and contributes increased LWD to the stream channel.

- *High flow*-Incubation life history stage, rated unknown impact**.** Continuous Tahuya River discharge data exists from 1945-1956 (PSCRBT 1991). The Salmon and Steelhead Stock Inventory (SASSI) (WDF et al. 1993) identified past logging and road building as contributing to increased peak winter flow events. It is impossible to quantify the extent of this problem without new stream gauge data. However, we know from studies of other watersheds that an increase of impervious surfaces translates into higher peak flows. Since winter flows are rain dominated, the numerous wetlands within the watershed

moderate peak winter flow. Development adjacent to lakes and wetlands increases the level of impervious surface translating into a reduction in available storage capacity at peak flow.

- *Subestuary habitat loss and degradation* — Juvenile rearing and migration life stage, rated low to moderate impact. Two areas of the delta, totaling >0.01 km^2 (~1 ac; 1.4% of historical delta area), appear to have been filled, primarily for residential development. Three areas of roads or causeways have impacted the delta over 0.27 km (0.17 mi) and, in addition to the habitat directly lost in the footprint of the causeways, the effect of this has been to constrict estuarine exchange in the middle of the delta. For example, a bridge at RM 0.0 with a fill causeway, constricts the migration, development, and flushing of estuarine sloughs. The extent of change in tidal flooding circulation and the effect on migrating and rearing salmon is unknown.

Factors for Recovery

A full discussion of protection options and restoration strategies by habitat factor is found in Part Three - section 3.4.4.2, toolkit.

- *Nearshore habitat loss*- Limit near shore development including, bulkheads, filling of near shore areas, erosion onto beaches, installation of docks, and loss of shoreline vegetation. Prohibit development that impacts or eliminates eelgrass beds, salt marsh and shoreline vegetation.

- *Riparian condition, species composition*-With adequate regulation and protection, the recruitment of LWD to the stream channels within the watershed should be expected to improve over the next 50 to 100 years as riparian forests mature. Only riparian forests of adequate width, age, and species composition will be capable of providing a full range of riparian functions. All forests within the channel migration zone (or 100 year floodplain) plus a riparian buffer of 250 feet should be protected.

- *Water quality, temperature*- Development of fully functional riparian forest will buffer stream temperatures.

- *Channel complexity*-The stream channel should be allowed to migrate naturally within the 100-year floodplain. This requires the elimination of bank hardening, stream channelization or other interruptions of channel and floodplain processes.

- *Peak flow*- Manage all activities within the watershed (logging and road construction, development, clearing, pavement, home construction, road building, placement of fill in and adjacent to lakes and wetlands) to eliminate increases in peak flow (see Peak Flow toolkit, Part Three - section 3.4.4.2). Implement storm water planning for existing and future development, including forest practice road construction. Size all drainage structures within the basin to allow for 100-year or larger storm events.

- *Subestuary habitat restoration* — The long-term refitting of the highway bridge across the subestuary would likely contribute to restoration of more natural tidal circulation and distributary channel structure in the middle of the delta. Education of the problems with dense hardening of the shoreline may be

necessary. Shoreline landowners can be offered incentives to retrofit bulkheads and rip-rap with "softer" technologies that are more habitat friendly.

Strength of Evaluation and Information Needs

Our understanding of the habitat conditions and sources of impact within the Tahuya River are based on instream habitat surveys, assessment of the riparian zone, and on the field knowledge of habitat by fisheries resource biologists. We are moderately confident that the above evaluation depicts the sources of impact and the likely effects on summer chum.

1. Presently the Tahuya River is not gauged. There is no available information for the extent that peak winter flows may be affecting chum survival on the Tahuya River.
2. The present data for stream temperature does not extend late enough into September to determine how long into fall elevated stream temperature effect adult migration and spawning.
3. A gravel scour monitoring program is needed. No information specific to the Tahuya River exists for bed stability and depth of gravel scour. In conjunction with gravel stability and scour, information on the level of fine sediment <0.85mm should be collected. The 1994 (Point No Point 1994) level of 10.5% is at the threshold where negative impacts to egg survival are expected.
4. Public education of the problems with bank hardening (bulkheads, riprap) of shorelines and the floodplain are needed, along with the importance of maintaining these edge habitats in forest.

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Dewatto Watershed Narrative
WRIA 15.0420

Watershed Description

The Dewatto River is located in the southwestern portion of Kitsap Peninsula, approximately 5.5 miles north of the Great Bend of Hood Canal, west of the Tahuya River, and south of Stavis and Big Beef creeks. Originating on the plateau of the Kitsap peninsula, the Dewatto follows a glacial outwash channel as it flows southwesterly and parallel to Hood Canal for approximately 8 miles to saltwater. The headwaters originate in till and outwash sands and gravels. The till is moderately erodible and the outwash is highly erodible. The narrowest portion of the valley is near the river mouth, but the confinement is not extreme. The watershed area is approximately 23 square miles and there are approximately 30 miles of tributary streams.

The Dewatto River gradient is low to moderate throughout its length flowing between gently rolling hills. The Dewatto enters Hood Canal through a mostly undisturbed estuary. Several large wetlands are directly associated with the mainstem, with numerous other tributary wetlands to the mainstem. The moderate terrain and low elevation of the watershed results in a rain dominated system where many small tributaries go dry early in the summer, or during winter dry periods. The numerous wetlands within the watershed are critical in moderating peak winter flow, and augmenting summer low flow. To provide instream flows during the summer low flow period, the Department of Ecology has closed the Dewatto River to additional consumptive appropriations during the time period June 15 to October 15, per WAC 173-515-040(2).

Historically, the prevailing land use in this sparsely developed watershed has been timber harvest, with a large portion of the watershed still managed for timber. Several Christmas tree farms are the only agricultural developments. Rural residences are scattered throughout the drainage. The riparian zone is 87% forested, the highest percentage of all 20 watersheds (Appendix Report 3.7). Rural homes account for 4% and agriculture 2% of riparian landuse

Summer Chum Distribution

The majority of summer chum spawn in the lower 2 miles of the Dewatto River. Stream flow and gradient characteristics would allow access to summer chum to approximately river mile (RM) 4.0.

Population Status

The summer chum population in the Dewatto River has been detected only in very low numbers since 1988, and is assumed to no longer be a self-sustaining population. A severe decline in the number of spawners has been recorded since the 1970s. In the 1970s escapement ranged between the hundreds and thousands, in the 1980s it was generally well below 100, and in the 1990s was zero or very few fish (Appendix Table 1.1).

Factors for Decline

Overall habitat quality in the Dewatto River was rated fairly high and in a state of recovery from historic logging practices, especially in comparison with adjoining watersheds. The estuary is an example of a high quality system that provides abundant transitional areas for adults and rearing habitat for juveniles. The lower river channel, where historically most of the summer chum spawned, remains today relatively undeveloped. Two factors of concern within the lower river are the elevated levels of fine sediment, and stream temperatures. Between 1915 and 1930 all the old growth timber in the Dewatto River watershed was harvested. Logging and road building has had direct and indirect impacts on the stream channel by decreasing volumes of in-channel large woody debris (LWD), and species diversity within the riparian forest. In the 1960s, the Washington Department of Fisheries Stream Improvement Division removed what was considered at that time as blockages to upstream salmon migration (Amato 1996). In the lower Dewatto River the summer chum habitat is degraded due to (in order of importance): elevated stream temperature, fine sediment within the spawning gravel, reduced channel complexity, loss of LWD, and the loss of species diversity within the riparian forest. For a comparison of the limiting factors in this watershed to other watersheds, refer to Part Three - section 3.4, Tables 3.17 and 3.18.

- *Water quality, temperature*-Adult spawning life history stage, rated high impact. Elevated water temperatures into late September can negatively affect summer chum by preventing the entry of adults into the river exposing them to predation. Water temperatures at or above 12 degrees Celsius extend through the first half of September for several years (PNPTC 1994, 1995, 1996, 1997). Reductions in the size of trees within the riparian forest will increase stream temperatures through a loss of shade and transpiration

- *Fine sediment* -Spawning and incubation life history stages, rated moderate impact. Spawning gravel composition sampling below RM 4.0 shows the percent of fines <0.85mm to be above the level where there are impacts to survival of incubating eggs. Levels were 15.1% in 1994 and 20.5% in 1995 (PNPTC 1995). Logging and road building may be the major factors contributing to elevated levels of fine sediment, however in-channel wetlands may also contribute. Elevated levels of fine sediment result in a loss of inter gravel flow and entombment of alevins and fry.

- *Channel complexity, large woody debris*-Spawning and incubation life history stages, rated low to moderate impact. From RM 3.0-3.5, there are 37% pools (high impact), 4.1 pool frequency (high impact) and 0.28 pcs/m of LWD (moderate impact). The survey is limited, and sandwiched between two large in-channel wetlands, which would increase percent pools and pool frequency. In the late 1960s, the Washington Department of Fisheries Stream Improvement Division removed logjams, debris, beaver dams and the channelized several miles of the Dewatto River. This effort degraded channel complexity and stability (Amato 1996).

- *Riparian condition, species composition*-Spawning and incubation life history stages, rated low to moderate impact By 1930 most of the old growth in the watershed had been harvested (Amato 1996). Historical riparian forests were dominated by a mixture of old growth cedar, western hemlock, Douglas-fir and areas of younger red alder, which now contain mixed stands of deciduous and coniferous species.

Stumps remaining in the riparian forest adjacent to the stream channel network show that in most areas all the large conifer trees available for recruitment into the stream channel were removed with timber harvest. Presently 32% of the riparian forest is less than 12 inches diameter breast height (<12 in dbh) and 68% is 12 to 20 inches dbh. Species composition of riparian forest is 96% mixed conifer and deciduous. Sixty nine percent of the riparian zone is greater than 132 feet in width, 16% 66 to 132 feet in width, and 15% less than 66 feet in width and/or sparsely vegetated. The riparian forest is in a state of recovery, and will continue to recover if not harvested in the future. Levels of LWD may decline for the next 25-50 years until the existing riparian forest matures and contributes increased LWD to the stream channel.

Factors for Recovery

A full discussion of protection options and restoration strategies by habitat factor is found in Part Three - section 3.4.4.2, toolkit.

- *Sediment fines*-Upgrade roads to route drainage away from stream channels. Re-vegetate or stabilize road sidecast, re-vegetate or armor ditch lines, and harden road surfaces to reduce the creation of fine sediment. Upgrade all stream crossing to pass 100 year events. Decommission roads, remove culverts, de-compact roads, outslope and waterbar road surfaces, and remove unstable fill and sidecast.

- *Channel complexity*-The stream channel should be allowed to function naturally within the 100-year floodplain. Natural function of the stream channel requires the elimination of bank hardening, stream channelization or other interruptions of channel and floodplain processes.

- *Riparian condition, species composition*-With adequate regulation and protection, the recruitment of LWD to the stream channels within the watershed should be expected to start to improve over the next 25-50 years as the present riparian forests mature . Only riparian forests of adequate width, age, and species composition will be capable of providing a full range of riparian functions. Stream segments with poor riparian condition and the inability of the channel to transport LWD of the size required from upstream areas, will require the riparian forest to be improved. The extent of the riparian forest must include the channel migration zone of the river to be capable of providing a full range of riparian functions.

- *Water quality, temperature* - As the riparian forests matures, stream temperatures will moderate.

- *Subestuary protection* – The subestuary is one of the remaining relatively undisturbed systems in Hood Canal and should be specifically sought for dedicated preservation or regulatory protection.

Strength of Evaluation and Information Needs

Our understanding of the habitat conditions and sources of impact within the Dewatto River are based on instream habitat surveys (channel, temperature, and fine sediment), analysis of riparian condition, and the

field knowledge of habitat by fisheries resource biologists. We are moderately confident that the above evaluation depicts the sources of impact and the likely effects on summer chum.

1. Presently the Dewatto River is not gauged. There is no available information on the relative magnitude and duration of peak flows.
2. The stream temperature data does not extend late enough into September to determine how long elevated stream temperature impacts adult migration.
3. A gravel scour monitoring program is needed. No information specific to the Dewatto River exists for bed stability and depth of gravel scour. In conjunction with gravel stability and scour, information on the level of fine sediment <0.85mm should be collected. Previous monitoring has shown fine sediment to be above levels considered safe for incubating eggs. This factor should be closely monitored.

References

Amato, C. 1996. Historical changes affecting freshwater habitat of coho salmon in the Hood Canal basin, pre-1850 to the present. Point No Point Treaty Council, Kingston, WA.

PNPTC (Point No Point Treaty Council). 1993, 94, 95, 96, 97. 1993-97 Ambient monitoring data (Unpublished). Point No Point Treaty Council, Kingston, WA.

Big Anderson Watershed Narrative
WRIA 15.0412

Watershed Description

Big Anderson Creek is located in southwestern Kitsap County. The stream enters Hood Canal approximately one-half mile north of the small community of Holly. The Big Anderson Creek watershed is approximately 5 square miles in area, with 4 miles of mainstem and 13 miles of tributaries (verified stream types 1-4). Similar to other streams in the West Kitsap WAU, Big Anderson Creek originates in headwater wetlands and flows through a confined ravine before opening into a broad floodplain in the lower one-half mile. The small estuary includes a large intertidal delta.

Land-use in the watershed is primarily industrial forestry operations conducted by several large landowners and the Department of Natural Resources. Logging in the Big Anderson most likely began in 1920s, with the establishment of Camp Union logging camp. Between the 1920s and 1944, the headwaters were entirely denuded with erosion observed in steep tributaries; and most of the remaining basin logged (MacLeod 1995). As the habitat recovered in the following decades, logging was again observed in 1984 aerial photos and continues to the present. Three private residences and a small farm are located in the lower mile of stream. A road bisects the floodplain near the mouth, and another road is adjacent to the river, and within the 100-year floodplain, from RM 0.5 to the mouth. Forty-five percent of the riparian zone is occupied by landuse, with 36% as roads and 9% agriculture (Appendix Report 3.8).

Summer Chum Distribution

Summer chum were recorded to spawn between river mile 0.0 and 1.1. Potential habitat is estimated to extend to at least river mile 1.8, which includes the lowest gradient reaches of the system.

Population Status

No summer chum salmon have been observed in standard surveys conducted by Washington Department of Fish and Wildlife since 1982 (one was observed in 1984). The population is assumed to be extinct. WDFW escapement estimates show the population ranging up to 234 in 1976 (Appendix Table 1.1).

Factors for Decline

Spawning and incubation habitat is moderately to highly degraded in the lower river from past logging and associated road building throughout the watershed. The habitat factors for decline, in order of priority, are: 1) increased sediment deposition in the lower mile from roads and landslides in the upper watershed, 2) increased magnitude and frequency of peak flows from road runoff, 3) loss of large woody debris (LWD) due to past logging of riparian zones and channel clearing activities, and 4) a county road built across the estuary and mouth of the stream that constrains the floodplain and may reduce sediment removal by tidal

action. For a comparison of the limiting factors in this watershed to other watersheds, refer to Part Three - section 3.4, Tables 3.17 and 3.18.

- *Sediment* - spawning and incubation life stage, rated high impact. Summer chum habitat is highly aggraded from logging roads, bank erosion and landslides. Effects are redd burial and suffocation, and channel instability. The spawning gravel includes a high percentage of fine sediment that can reduce survival during the incubation stage. Some of the high levels of fine sediment are attributed to extensive beaver pond construction in the lower half mile.

- *Riparian condition* - spawning and incubation life stage, rated high impact. Seventy seven percent of the riparian zone is deciduous dominated and 44% of it contains small diameter trees. Fifty nine percent of the riparian zone contains forested buffers <66 ft in width (Appendix Report 3.7). Future LWD recruitment potential is limited due to narrow forested buffers with low levels of conifer.

- *Channel complexity* - spawning and incubation life stage, rated moderate impact. Below RM 1.8, the channel contains 0.3 LWD pieces/m (moderate impact), 51% of the habitat area is in pools (moderate impact), and a pool frequency of 1.7 per channel width (low impact-Tabor 1994) (Appendix Report 3.8). Beaver activity has increased the percentage of pools. Eighty seven percent of LWD pieces are smaller than 20 in. diameter (Appendix Report 3.7). Minimum "key piece" diameter for LWD is 22 in for a channel of this size (Washington Forest Practices Board 1995). Compared to historical levels, the channel is degraded, but is in comparatively better condition than many other watersheds we examined. However, the channel is also unstable and braided, with high sediment loading and peak flow problems. It is expected that channel condition will deteriorate for at least the next several decades due to the poor riparian condition and mass wasting in the upper watershed.

- *Peak flow* - incubation life stage, rated moderate impact. Increased frequency, magnitude and duration of peak winter flows caused by extensive road building is thought to contribute to the bank erosion, channel aggradation and channel instability observed in the lower reaches of the stream. High flows coupled with an unstable channel will increase the depth of scour and redd mortality.

- *Sub-estuary habitat loss and degradation* — Juvenile rearing and migration life stage, rated moderate impact. One road crosses the delta, and another road follows the northern subestuary margin, totaling 0.24 km (0.15 mi) in length. The roads were identified as one of two primary factors for degradation of the sub-estuary, however the amount of change in tidal flooding circulation due to the roads is unknown. The second factor is old railroad fill, which is downstream of the two roads described above and located directly within the subestuary. While all of the estimated historic delta area of approximately 0.12 km^2 (28.9 ac; 1.78 km [1.1 mi] perimeter) appears to be inundated by tidal flow, the old roadbed in the subestuary constricts tidal circulation to the main channel. An oyster farm covers about 0.01 km^2 (0.8 ac; 2.74% of original delta area) in the outer edge of the delta. This feature does not appear to impact summer chum rearing or migration. Dredging, excavation, docks, and log storage are not evident in the subestuary.

Factors for Recovery

The following recommendations are provided to allow recovery of Summer Chum habitat in the lower river. A full discussion of protection options and restoration strategies is found in Part Three - section 3.4.4.2, toolkit.

- *Riparian forests/channel complexity* – Protect and restore the riparian floodplain forests along the entire 1.8 river miles of documented summer chum habitat. Below RM 1.0, plant conifers throughout the floodplain. Recruitable LWD of sufficient diameter will be available from newly planted seedlings in 50 to 100 years. In the interim, the amount and size of LWD will decline. Increase riparian buffer protection throughout the watershed. The WDNR (1995) prescriptions may not provide for adequate long-term recruitment of LWD to the stream system.

- *Floodplain*- Relocate roads outside of the floodplain, or replace road fill with causeways that allow channel movement and passage of floodwater (includes two roads described in the sub-estuary section plus another road located on the south side of the floodplain). Modification (e.g., setback, rerouting) of roadways would enhance summer chum migration, spawning, and incubation habitat. The floodplain is mostly owned by one timber company. The Hood Canal Salmon Sanctuary continues to work with the landowner on obtaining riparian easements or purchase of this property.

- *Sedimentation*-Prevent logging on potentially unstable slopes, and remove or repair roads with surface erosion or landslide hazard problems. The WDNR (1995) prescriptions provide some protection from unstable slopes problems, but this level of protection may need to be re-evaluated.

- *Peak flow*-Decommission roads, increase the number of water bars and cross drains on forest roads, identify and re-direct road ditches that contribute rainwater directly to stream channels, and limit new road construction in the watershed.

- *Sub-estuary*-Remove the abandoned railroad fill to improve tidal circulation. This will enhance summer chum rearing and migration habitat.

Strength of Evaluation and Information Needs

The Department of Natural Resources sponsored the WDNR (1995) that provides an in-depth assessment of habitat conditions in Big Anderson Creek and other streams. This coupled with the riparian and landuse assessment provides sufficient data to assess the factors for decline. However, the relative importance of LWD, sediment, or peak flows in causing channel degradation is not well understood. Further research in these areas is needed. Confidence in the assessment is high.

1. Gauge the stream. It is impossible to monitor the effects of peak flow on incubating eggs without gauge information.
2. Scour chain surveys to monitor bed instability throughout the summer chum reach.

3. McNeil sediment surveys to determine the level of fine sediments throughout the summer chum reach.

References

Amato, C. 1996. Historical changes affecting freshwater habitat of coho salmon in the Hood Canal basin, pre-1850 to the present. Point No Point Treaty Council, Kingston, WA.

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Stavis Watershed Narrative
WRIA 15.0404

Watershed Description

The Stavis Creek watershed is located in the northeastern portion of the Hood Canal on the Kitsap Peninsula, 3 miles southwest of the town of Seabeck. The watershed area is about 7 square miles, with 5 miles of mainstem, and 11 miles of tributary habitat.

The Stavis Creek watershed is typical of stream systems on the Kitsap Peninsula (see description under Seabeck Creek). Stavis Creek originates in a series of beaver ponds, forested and emergent wetlands located on a flat glacial till plain. Several watershed reports have listed Morgan Marsh as the headwaters of Stavis, Big Beef, and Tahuya River. Field investigations have shown Stavis Creek is not directly connected with Morgan Marsh although groundwater interchange is likely. The mainstem then flows in a northeasterly direction in steep, tightly confined ravines for approximately 3.5 miles. Below the junction with tributary 15-0405 the channel gradient moderates and is unconfined, eventually emerging into a relatively broad floodplain, high quality estuary and Stavis Bay. The estuary and delta are not impacted to any substantial degree, and represents one of the better undisturbed examples of estuarine lagoon and spit features in Hood Canal.

The majority of base flow to area streams is provided through hydrologic continuity with a shallow perched aquifer with a smaller contribution via indirect hydrologic continuity with a deeper aquifer known as the Seabeck Aquifer (Becker, 1998). The Seabeck Aquifer contributes baseflow near the mouth of several streams including Little Anderson, Seabeck, and Big Beef creeks. The western boundary of the Seabeck Aquifer is indistinct, but given similarities in landform and geology, is assumed to include Stavis Creek. Stream flow data specific to Stavis Creek is not consistently available, although instaneous readings include minimum flows of 1 cfs (May et al. 1995).

Historically, land use in this area was dominated by timber extraction activities with two major cycles of timber harvest (see history under Seabeck Creek). The area of Stavis Creek headwaters, similar to Seabeck Creek, was connected to a network of timber railroads by 1927, but appeared to be spared the heavy logging seen in other watersheds. Aerial photographs in 1944 show large areas of large trees, and intact marshland in the lower basin (MacLeod, 1995).

Current land use in the watershed is a mixture of rural residential scattered along the shorelines, lower half mile of the stream and upper basin. Forestry is a major land use, with Department of Natural Resources managing a large block of land for timber production, the Kitsap Forest Natural Area Preserve, and limited private forest lands. Conservation easements to protect the primary summer chum range are currently being negotiated by the Washington Department of Fish and Wildlife through the Hood Canal Salmon Sanctuary. The watershed has undergone less development that adjoining Seabeck Creek, but has been actively managed for timber production in the last 30 years. Shoreline development and associated impacts

(bankhardening, bulkhead construction, and loss of shoreline vegetation) is focused primarily on the shoreline to the east of Stavis Creek, but at lower concentration than the shoreline near Seabeck.

Summer Chum Distribution

Stavis Creek is included in this plan based on the potential for historical summer chum utilization given available suitable habitat, stable late summer flows, and similarities to nearby Big Beef Creek that is known to support summer chum. Based on habitat features, distribution is assumed to have occurred from RM 0.0 to RM 0.6.

Population Status

Summer chum salmon have not consistently been surveyed or reported in spawning surveys conducted by WDFW or the Tribes. The tribes reported 6 live and 3 dead summer chum in three September surveys conducted in 1983, and one summer chum was found in a 1981 survey. A survey by a University of Washington scientist found no chum in one survey in 1968, and 75 chum in an October survey in 1972.

Factors for Decline

Overall, habitat quality within Stavis Creek was rated fairly high and in a state of recovery from historic logging practices, especially in comparison with adjoining watersheds in the Hood Canal sub-region. This can be attributed to the relatively low density of residences, roads and other intrusive landuses. The total impervious surface area for the basin is 1.5%, with the majority of those surface not connected to the stream network (May et al 1997). The estuary is an example of a high quality system that provides abundant transitional areas for adults and rearing habitat for juveniles. The lower 0.6 miles provides high quality spawning and rearing habitats, with only minor impacts from several residences and one bridge crossing of the stream near the mouth of the creek. No fish passage problems were noted. For a comparison of the limiting factors in this watershed to other watersheds, refer to Part Three - section 3.4, Tables 3.17 and 3.18.

Habitat factors rated as contributing to the decline of summer chum (in order of importance) include:

- *Sediment (aggradation and degradation)*-Spawning and incubation life stages, rated moderate impact. Limited scour chain monitoring in the lower reaches indicate areas of moderate scour and fill associated with peak winter flows with potential impacts to egg incubation (May et al, 1997). Sources include logging that has contributed to mass wasting events and historic removal of LWD.

- *Riparian forest (species composition)*-Spawning and incubation life stage, rated moderate impact. Riparian zones which were historically dominated by a mixture of old growth cedar, douglas fir, and areas of younger alder are now more dominated by mixed stands of deciduous and coniferous species (58%) and deciduous dominated (42%), generally 50 to 70 years old (WDNR, 1995, Appendix Report 3.7). While these stands are on a trajectory of recovery, it will take approximately 50 to 100 years more to achieve old growth conditions that provided the most stable and complex habitat. Riparian forest composition has an impact on the quality of wood recruited to the channel, which in turn effects the

stability of the channel during the egg incubation stage. Eighty-three percent of the total riparian area evaluated in Stavis Creek is forested, indicating a fairly sizable and intact riparian forest within the presumed distribution of summer chum.

- *Flow (winter peak flow)*-Incubation life stage, rated potential but unknown impact. Historic and current logging practices and associated roads are responsible for altering hydrologic patterns and increasing the rate of mass wasting events, although the relative magnitude of changes in the hydrologic regime is unknown.

Factors for Recovery

Protect existing high quality habitat

- Continue and expand the acquisitions efforts underway by the Hood Canal Salmon Sanctuary. Priority areas should include estuary, adjoining shoreline areas, lower mainstem and floodplain, and upstream wetland hydrologic source areas. The estuary and associated bordering uplands should be explicitly protected or regulated to prevent any further development.

Protect and restore riparian forest quality

- For properties acquired in lower watershed that are lacking riparian forest, reforest riparian areas with appropriate native species and abandon any associated roads.
- Provide upstream recruitment sources by reforesting narrow riparian zones on upstream DNR lands.
- Consider limited silvilcultural treatments on alder dominated zones to encourage conifer regeneration within summer chum range on WDFW properties.
- Work with Kitsap County to establish appropriate riparian zone widths for upstream areas to provide long term LWD recruitment sources.
- Evaluate the effectiveness of West Kitsap Watershed Analysis prescriptions for logging operations to reduce mass wasting events and modify prescriptions if necessary.

Establish hydrologic maturity targets for basin

- Establish rate of harvest targets for forestry activities to ensure hydrologic maturity.
- Work with Kitsap County to maintain low densities within basin.
- Develop mitigation standards for development activities that create impervious surface greater than 10% of lot size.

Monitoring/reference site

- Utilize the Stavis Creek estuary as a critical habitat template for eastern Hood Canal, establish long-term monitoring programs to track estuarine quality including macroinvertebrate populations, water quality, channel structure and complexity.

Strength of Evaluation and Information Needs

Confidence for fish distribution is rated low based on the extremely limited spawning data for Stavis Creek. Considerably more data is available on habitat conditions, including temperature, limited instream flow,

scour chain, TFW ambient monitoring and an assessment of channel, riparian, and instream habitat conditions conducted through the West Kitsap Watershed Analysis. Confidence for habitat data is rated as high. Overall confidence for the assessment is moderate.

Additional information needed to better quantify the relationship between current conditions and summer chum distribution includes:

1. Instream flow monitoring of both summer flow periods and peak winter flows;
2. Channel assessments to determine the relationship between peak flows and channel forming events.

References

Becker, J. 1998. Aquifer modeling and mitigation options for the Seabeck aquifer system. Pub. Util. Dist. 1, Kitsap County, Bremerton, WA.

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WDNR (Washington Department of Natural Resources). 1995. West Kitsap Watershed Analysis. Wash. Dept. Nat. Res., South Puget Sound region office, Enumclaw, WA.

Seabeck Watershed Narrative
WRIA 15.0400

Watershed Description

The Seabeck Creek watershed is located in the northeastern portion of the Hood Canal on the Kitsap Peninsula near the town of Seabeck. The watershed area is about 6 square miles, with 5 miles of mainstem, and 16 miles of tributary habitat.

The Seabeck Creek watershed is typical of streams on the Kitsap Peninsula. These systems are rain-dominated watersheds with low elevation flat and rolling terrain dissected by deeply incised stream ravines, small to moderate sized estuaries, and extensive nearshore habitat. The geology of the area is dominated by glacial materials, which are prone to erosion and moderate to high sediment production rates within the confined stream ravine reaches.

The majority of base flow to area streams is provided through hydrologic continuity with a shallow perched aquifer with a smaller contribution via indirect hydrologic continuity with a deeper aquifer known as the Seabeck Aquifer (Becker 1998). The Seabeck Aquifer contributes baseflow near the mouth of several streams including Little Anderson, Seabeck, and Big Beef creeks. The western boundary of the Seabeck Aquifer is indistinct, but given similarities in landform and geology, is assumed to include Seabeck Creek. The stream is currently closed to further surface water appropriations.

Seabeck Creek originates in headwater wetlands located on a flat glacial till plain. The mainstem then flows in a northerly direction in steep tightly confined ravines for approximately two miles. Below the junction with tributary 15-0401 the channel gradient moderates and is unconfined, eventually emerging into a relatively broad floodplain, small estuary and Seabeck Bay. A small tributary to the east of the mainstem also feeds into the estuary. The estuary has a comparatively narrow delta that is heavily encroached upon by residential development on the east side.

Historically, land use in this area was dominated by timber extraction activities. Seabeck was the site of a major timber mill that began operations in 1857 and continued until the mill burned in 1886. The Seabeck mill concentrated on harvesting old growth timber along easily assessable waterways such as shorelines and streams. Another major period of timber extraction continued from 1920 to 1936 with the establishment of Camp Union in the upper Big Beef watershed. At the peak of operations, over 1.5 million board feet of timber per day was cut in the watersheds surrounding Camp Union, and railroad spurs were constructed in the valley bottom of Seabeck Creek to facilitate transport of timber. By 1944, most of the Seabeck Creek watershed (except for the headwaters near Hite Center) had been completely harvested (MacLeod 1995)

Current land use in the watershed is a mixture of rural residential, forest lands, small scale hobby farms, limited aquaculture, the nearby town of Seabeck, and a marina. The watershed has undergone a dramatic increase in rural development over the last ten years as evidenced by increases in application for land use and hydraulic permits. In particular, applications to convert forest land to rural development have

accelerated since the late 1970s. Shoreline development and associated impacts (bank hardening, bulkhead construction, and loss of shoreline vegetation) is especially heavy on the shoreline to the east of Seabeck Creek.

Summer Chum Distribution

Summer chum salmon have not been reported in spawning surveys conducted by WDFW or the Tribes. Surveys conducted in late September and October for 1981 and 1983 found no summer chum in the watershed. Seabeck Creek is included in this plan based on the historical potential for summer chum utilization given available suitable habitat, stable late summer flows, and proximity to adjacent watersheds (Big Beef Creek) which have supported summer chum. Based on the presence of suitable habitat, we expect summer chum could have occurred up to RM 0.9 on the mainstem, RM 0.5 on Tributary 15-0401, and to RM 0.3 on an unnamed tributary flowing from the east to the mainstem.

Population Status

Limited survey data for summer chum indicate that a summer chum population does not exist at this time. However, habitat and flow conditions appear conducive to summer chum and it is possible that prior to spawning surveys summer chum did historically occupy the watershed.

Factors for Decline

Impacts to habitat quality include: 1) Coarse sediment aggradation and high levels of fine sediment in spawning gravel; 2) loss of channel complexity; 3) altered hydrologic patterns; 4) degraded riparian conditions and 5) floodplain connectivity. Sources of impacts are historic and current logging and rural development patterns in the Seabeck Creek watershed. For a comparison of the limiting factors in this watershed to other watersheds, refer to Part Three - section 3.4, Tables 3.17 and 3.18. More details are provided below:

- *Sediment (aggradation, degradation, and fine sediments)*-Spawning, incubation, migration life stages, rated high and moderate impact. The lower two miles of Seabeck Creek show evidence of increased sediment bedload, to the extent that the some sections of the stream go subsurface in early summer in many years (WDNR 1995). Sediment aggradation has also caused a decrease in channel complexity with the end result of increased flooding frequency with relatively minor precipitation events. While the glacial geology of the area is prone to high sediment production rates, the effects of historic logging practices coupled with minimal protection of riparian areas in rural development and current logging has accelerated the rate and magnitude of slope failures and overwhelmed the capacity of stream channels to process these sediments. Areas of localized scour were also noted during the West Kitsap Watershed Analysis, especially in the reach just above the lower bridge crossing on Stavis Creek Road. The end result of channel aggradation and instability on summer chum includes: 1) upstream passage of adults is hindered due to insufficient stream flow and lack of deep holding pools; 2) reduction in egg survival due to scour of egg pockets during increased winter peak flows; 3) downstream migrating juveniles are subjected to increased predation due to loss of stream depth and cover.

TFW Ambient Monitoring data (1989) indicates high rates of embeddedness in spawning gravels related to increased levels of fine sediment. Increased fines are primarily linked to surface water runoff from roads in the watershed, many of which are private and have minimal maintenance and inadequate surfacing. Fine sediment is also linked to improper logging, and runoff from impervious surfaces associated with rural development. Inadequate treatment of runoff from recent rural development such as Seabeck Heights, especially when construction occurs during wet weather conditions, have contributed significant amounts of fine sediment episodically to the channel. Seabeck is located within a rapidly growing rural area, with a total effective impervious rate of 2.7% (May et al 1997) which is expected to increase over time. Diminished chum populations in the watersheds of the eastern Hood Canal may also impact gravel quality. The effectiveness of chum salmon in cleaning gravels associated with redd building activities has been noted by several researchers (Montgomery et al. 1996; Peterson and Quinn 1994b).

- *Channel complexity (LWD, channel condition, loss of side channel habitat, and channel instability)*- Spawning, incubation, and migration life history stages, moderate and high impact. The amount of LWD in Seabeck Creek has been diminished from historic levels through actions such as stream cleanout, logging without leaving streamside buffers, and rural development. Channel complexity is closely linked with large woody debris as log jams form hard points, deflecting flow and causing the formation of side channel habitat, a limited habitat type within the Seabeck Creek watershed. Reduced channel capacity has also altered the hydrologic regime of the channel, causing lower summer flows and increased winter peak flows.

- *Flow (winter peak and summer low flows)*-Spawning and incubation life stages, rated moderate impact. Related to increased sediment load and modifications in channel capacity, winter peak flows have increased and summer flows frequently are substantially diminished within the upper portion of the historic summer chum range, although the relative magnitude of the problem is unknown due to a lack of stream flow data specific to Seabeck Creek. The end result has been displacement of incubating eggs and suboptimal conditions for spawning adults.

- *Floodplain connectivity*-Rearing and migration life history stages, rated high impact. Rural development, channel alteration, and altered flow patterns due to the bridge crossing have affected the quality of the Seabeck floodplain. Illegal clearing of streamside areas and attempts to fix the channel in place are common problems within the lower 0.5 miles of the stream.

- *Riparian condition (species composition, age, and width)* - Spawning and incubation life stage, rated moderate to high impact. Riparian zones which were historically dominated by a mixture of old growth cedar, douglas fir, and areas of younger alder are now more dominated by mixed stands of small- (<12 inch dbh) to medium-sized (12-20 inch dbh) trees within the distribution of summer chum. Mixed deciduous and coniferous stands comprise (59%) and deciduous dominated stands (41%) of the riparian forest. Below RM 0.9, the riparian forest is significantly impaired, 100% of the area having a sparse buffer less than 66 feet, due to residential development, roads and dikes (Appendix Report 3.7). The

generally degraded condition of riparian forest suggests that critical functions such as LWD recruitment, will remain limited for the foreseeable future, unless active restoration steps are taken.

- *Estuarine habitat loss and degradation* — Juvenile rearing and migration life stage, rated moderate to high impact. Fills for recreational, and some commercial use including shoreline-dependent marina activities, include two areas totaling 0.01 km^2 (3.6 ac; ~8.9% of historical delta area). The residential development appears to have extracted a significant portion of the mid- to lower delta summer chum rearing area. Associated bulkheads and armoring have also impacted shoreline migration. Although the Seabeck marina is located on the outer margins of the delta, the associated docks do not appear to directly impact the delta because of their position over deeper water, receiving a low impact rating.

Factors for Recovery

A discussion of protection options and restoration strategies in terms of these habitat factors is found in Part Three - section 3.4.4.2, toolkit.

Control coarse and fine sediment sources
- Evaluate the effectiveness of existing slope stability standards (West Kitsap Watershed Analysis, Kitsap County Critical Areas Ordinance) and modify if necessary.
- Improve road maintenance and surfacing on existing private roads, paying particular attention to the routing of stormwater runoff onto vegetative surfaces prior to entering the stream system.
- Enact timing restrictions for clearing and grading activities in areas adjacent to Seabeck Creek.

Restore channel complexity
- Evaluate the feasibility of restoring large woody debris jams in the lower river.

Protect low flow conditions and prevent increases in peak discharge
- Prohibit additional withdrawals of surface water or ground water in hydraulic continuity with Seabeck Creek until an instream flow has been established.
- Establish impervious surface target rates for basin and condition landuse permit consistent with this standard.
- Retrofit existing developments to control stormwater runoff.
- Maintain 60% of the watershed in forest cover through low densities and site design to maximize retention of native plant cover.

Protect and restore riparian forests
- Acquire remaining high quality riparian forest habitat and replant riparian buffers using native species.
- Review and adjust the Kitsap Critical Area Ordinance standards consistent with the recommendations given for functional riparian buffers.

Protect remaining estuarine features
- Given the extent of development already imposed on the delta, further modifications to the estuary should be prevented by land acquisition or regulation.

Strength of Evaluation and Information Needs

Confidence for fish distribution is rated low, and based upon professional judgement of where summer chum would likely spawn. A considerable amount of data is available on habitat conditions, including temperature data, limited instream flow, and an assessment of channel, riparian, and instream habitat conditions conducted through the West Kitsap Watershed Analysis and confidence is rated as moderate.

Information needs for Seabeck Creek include continuous monitoring of instream flows, sediment source surveys, and an assessment of channel capacity.

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Big Beef Watershed Narrative
WRIA 15.0389

Watershed Description

Big Beef Creek is located in the northeast portion of Hood Canal on the Kitsap Peninsula, 2 miles northeast of the town of Seabeck. The watershed area is about 14 square miles, with 11 miles of mainstem, and 24 miles of tributary habitat (source: SSHIAP database, PNPTC 1988).

The geomorphology of Big Beef Creek watershed is typical of stream systems on the Kitsap Peninsula where glacial action deposited loose, unsorted coarse gravel and sand (see more detailed description under Seabeck Creek). Big Beef Creek has the largest drainage area and most extensive stream network for watersheds supporting summer chum in northeastern Hood Canal. Upper Big Beef Creek consists of low gradient reaches originating from a series of wetlands, including Morgan Marsh on tributary 15.0398. An artificial lake (Lake Symington) at RM 5.3 was constructed in the 1964 to accommodate lakeshore residential development. Lower Big Beef Creek (RM 2.0 to 5.3) is contained within a steep, moderately confined ravine. The valley walls widen below RM 2.0 and channel gradient moderates to less than 1%. In this area the river includes a fairly well developed floodplain and complex side channel habitat. The Big Beef estuary is 47.7 acres in a semi-enclosed lagoon.

The majority of base flow in Big Beef Creek is provided through hydrologic continuity with a shallow perched aquifer with indirect hydrologic continuity from a deeper aquifer known as the Seabeck Aquifer (Becker 1998). The Seabeck Aquifer contributes baseflow predominantly at the mouth of Big Beef Creek. Minimum streamflow averages 3.1 cfs and maximum flows average around 200 cfs, with a maximum discharge of 1,500 cfs recorded in 1967 (Lestelle et al. 1992, Cederholm 1972).

In the past, the prevailing land use in the upper watershed has been timber harvest; some lands are still managed for harvest of timber resources including several large blocks of land managed by the Department of Natural Resources. Historic logging activities began in earnest with the establishment of Camp Union in 1920, with the entire watershed above RM 5.0 to the headwaters logged by 1950 (Amato 1996). Agricultural developments exist at several locations along the upper stream reaches. Since 1970, residential development has proliferated, especially concentrated around and just downstream of Lake Symington. Lake Symington has had a primary impact on the lower system; lake levels and downstream flows were for many years managed to meet the needs of the lakeshore residents, with little regard for effects on downstream flows. WDFW has recently incorporated provisions in the lake's rules of operation to protect downstream flow requirements of fisheries resources. Below Lake Symington, there is limited residential development along the stream with the majority occurring on the flat till plain above the river. The University of Washington's 320-acre fisheries research facility is located between RM 0.0 to 0.8. Washington Department of Fish and Wildlife operates a weir at RM 0.1 to count upstream and downstream coho salmon migrants. The Hood Canal Salmon Sanctuary program has actively been purchasing key riparian habitat upstream of the U.W. research facility.

Summer Chum Distribution

Before the disappearance of summer chum from Big Beef Creek, the majority of the spawning population is believed to have occurred in the lower reaches of Big Beef Creek up to RM 2.0. However, summer chum may have historically occurred as far upstream as RM 6.0 (inlet of Lake Symington) or perhaps even further upstream. A significant portion of summer chum spawning may have also occurred intertidally in the protected subestuary.

Population Status

Escapement estimates for 1975 and 1976 exceed 1,000 spawners, although most surrounding years are in the low hundreds. No summer chum have been reported since 1982, with the exception of 22 in 1984. The population is assumed to be extinct. In 1996, an experimental program to reintroduce summer chum to Big Beef Creek was begun by the co-managers at the U.W. research facility.

Factors for Decline

A general discussion of protection and restoration strategies for each habitat factor is found in Section IV, toolkit. Impacts to habitat quality (in order of priority) include: 1) Coarse sediment aggradation and high levels of fine sediment in spawning gravels; 2) loss of channel complexity; 3) alteration of estuarine habitats; 4) altered hydrologic patterns; 5) degraded riparian conditions; and 6) potential elevated temperatures. Sources of impacts are historic and current logging, rural development patterns, and construction and operation of scientific research facilities in the Big Beef watershed. For a comparison of the limiting factors in this watershed to other watersheds, refer to Part Three - section 3.4, Tables 3.17 and 3.18. More details are provided below:

- *Sediment (aggradation, fines)*-Spawning, egg incubation, and migration life history stages, rated high impact. The lower river channel, where historically most of the summer chum production occurred, has been severely impacted by upstream landuse practices, with concurrent reductions in survival in all life history stages. Past logging and road building on steep unstable slopes in the lower Big Beef watershed have caused mass wasting, channel widening and bank instability, causing a 800% increase in sediment bedload over natural, undisturbed conditions (Madej 1978, 1982). The majority of this coarse sediment has been deposited within the lower stream reaches, reducing available pool habitat and causing the channel to widen and become more shallow (WDNR, 1995). Channelization, along with the construction of the WDFW fish weir, has also increased aggradation by constricting the channel and forcing the bedload to be deposited upstream from the weir. The bridge causeway on the Seabeck Road has also restricted the freshwater-saltwater interface and reduced the potential flushing action of sediment associated with tidal action.

  During summer low flow periods, the aggraded and widened channel has been reported to impede upstream passage and reduce spawning success for adult summer chum due to increased predation associated with loss of stream cover (Cederholm, 1972). In 1969 and 1971, the entire summer chum run was moved into the UW Research Station spawning channel because of unstable conditions in the main

channel and in anticipation of channelization activities (see description below). Cederholm (1972) documented a 58% loss of summer chum redds due to scour, fill, and channel displacement, with an average survival to emergence rate of 9.4%. In the same study, he noted 16.3% fine sediment (less than 0.8 mm in diameter) in spawning gravel, a rate at which permeability and intergravel survival would be substantially diminished.

- *Channel complexity (LWD, channel condition, loss of side channel, channel instability, floodplain connectivity)*-Spawning, egg incubation, rearing, and migration life history stage, rated high to moderate impact. Channel alterations, in combination with sediment aggradation described above, have reduced channel complexity in lower Big Beef Creek, affecting all major life history stages. Monitoring data collected in 1993 and 1994 indicated 0.17 pieces of LWD per meter, rated as a high impact (Appendix Report 3.8). Pool habitat is rated as moderate impact (46% percent pools, pool spacing of 2.4) with the majority of pools being formed by the roots of standing trees or old growth stumps, and log jams anchored by remnant old growth LWD (PNPTC 1993,1994). In a recent field review of Big Beef Creek, Cederholm noted the loss of stable, deep pools present in the 1960s associated with the loss of LWD and sediment deposition in the lower river.

  Reduced LWD levels have been attributed to illegal cedar salvage, stream cleanout of log jams, channelization activities (S. Neuhaueser, pers. comm.; Amato 1996). At least three separate incidents of channel dredging, dike construction, wood removal, and channel relocation by private landowners have been documented in the lower river from the 1950s (Amato 1996). In response to extreme channel aggradation and braiding in the lower river, and concerns for stranding and reduced survival of summer chum, the University of Washington channelized 1,968 feet of the lower river in 1969 (Cederholm 1972). At the same time, the U.W. constructed dikes consisting of excavated gravel on the southwest side of the river, further constricting the floodplain and creating a new sediment source for downstream areas. Channelization attempts were largely unsuccessful in dealing with sediment aggradation and channel instability in lower Big Beef Creek.

  Routine spot dredging upstream of the weir has occurred since the 1970s, with deposition of dredge spoils along the bridge causeway and a floodplain service road. Diking, construction of a road within the floodplain to service an artesian well for the Big Beef rearing facility operated by NMFS, and filling and alteration of side channel habitat associated with the construction and operation of the Big Beef Research Station, have also contributed to reduced channel complexity in the lower 2 miles of the river.

- *Subestuarine habitat loss and degradation* - Juvenile rearing and migration life stages, rated high impact. The research facility, road, bridge construction and sediment aggradation near the mouth of the stream have decreased the quality and amount of the subestuarine habitat that is most immediately available to emigrating summer chum fry. Three areas, totaling 0.64 ac or 1.4% of historic delta area have been filled; this filling, as with evacuation of one pond covering <0.72 acres or 1.5% of the historic delta area, is associated with the fish research and culture facilities of the Big Beef Research Station. A fish counting weir operated by WDFW, tends to act as a channel constriction and sediment trap, affecting upstream channel conditions and sediment transport processes into the estuary. Historically, timber from

logging operations in the area was dumped from trucks into Big Beef Harbor upstream from the sandspit at the harbor's mouth where they were rafted to adjacent mills (Amato 1996).

The Seabeck Road bridge and its associated causeway crosses 0.03 mile of the middle reach of the delta, essentially narrowing the opening previously associated with a sandspit originating on the east side of the estuary. Aerial photographs from 1947, 1961, and 1997 show that extension and reinforcement of the bridge causeway has significantly constrained tidal interaction with the estuary, causing the estuary to infill with sediment, and reducing channel complexity. This observation is reinforced by historic accounts that at one time, small boats were able to navigate into the estuary and lower channel (S. Neuhaueser, personal communication). Adult intertidal spawning may also have also been impacted by these changes.

- *Flow (summer low flow and peak winter)*-Spawning, egg incubation, and migration life history stages, rated moderate and high impact respectively. Summer low flows that occur during late August through the end of September, especially during natural drought cycles, have impacted adult migration and spawning success. Reports of adult stranding were recorded in the late 1960s and 1970s, mostly as a result of channel aggradation (Cedarholm 1972). Future withdrawals of water for domestic water supply, both from the shallow perched and deeper aquifer, have the potential to further compound the problem. The contribution from the Seabeck Aquifer to baseflows at the mouth of Big Beef Creek, is considered important, since the zone of influence overlap almost perfectly with the area of summer chum distribution.

  Winter flood flows have increased as a result of upstream urbanization effects, logging, road building and manipulation of flows at Lake Symington. As of 1993, 3.1% of the watershed was covered by impervious surfaces, approaching a rate at which changes to habitat quality are first noted (May et al. 1977). Changes in the duration and magnitude of peak flows with relatively minor precipitation have been observed since the late 1980s (WDNR 1995). This causes channel instability, including greater scouring and filling of sediments in the channel. May et al. (1997) noted several incidences of scour in excess of 22 cm, the typical depth for egg deposition.

- *Riparian forest (species composition, age)*-Spawning and incubation life stages, rated moderate impact. Riparian zones which were historically a mixed forest of old growth cedar with limited areas of deciduous species associated with disturbance regimes (primarily windthrow and channel migration) are now predominantly composed of mixed conifer and deciduous (47%), deciduous species (48%) and 36% less than 12 inches in diameter (Appendix Report 3.7, WDNR 1995). In comparison to adjoining watersheds, the riparian forest of lower Big Beef Creek is relatively intact (76% of the total riparian length having a buffer greater than 132 feet, low impact rating), with only minor areas of narrow riparian zone related to logging and limited residential developments (at RM 3.5 and below Lake Symington). Other land use impacts to the buffer include roads, dikes, and the UW Research facility in the lower river.

- *Water quality (temperature)*-Migration and spawning life stages, rated moderate impact. Temperature monitoring conducted in 1996 and 1997 indicated temperatures above the optimal target of 7-12 degrees

Celcius in the lower basin, with increasing temperatures at sites within 2 miles of Lake Symington. Lake Symington is a shallow artificial lake prone to heating. Other factors compounding the effects of Lake Symington include channel widening and associated loss of riparian cover, and potential impacts from groundwater extraction. The extent of impairment on migration and spawning is unknown.

Factors for Recovery

Reduce sources of sediment aggradation

- Reduce the rate and magnitude of mass wasting within the lower five miles by prohibiting logging and development on steep, unstable slopes.
- Monitor the effectiveness of current prescriptions adopted for logging (West Kitsap Watershed Analysis) and rural development (Kitsap County Critical Areas Ordinance).
- Address sediment contribution from existing abandoned or active roads, and correct known problems. Of special concern, is the Kidhaven Road at RM 3.2.
- Prohibit construction of new roads on steep ravine slopes below Lake Symington.

Increase channel complexity

- Remove the service road located within the floodplain (RM 0.5) and evaluate the feasibility of restoring several side channels and wetlands adjoining the U.W. research facility.
- Evaluate the role of the WDFW fish weir in changing sediment routing patterns and investigate options for reducing its impact.
- Evaluate the need for placing LWD jams in the lower river through a feasibility study.

Reduce road and causeway constriction of estuarine delta

- Long-term planning for replacement or retrofitting of roadway should consider expanding the bridge span and reducing the foodprint of the roadway on the historic delta in order to maximize the opportunity for full creek-tidal water exchange and circulation.

Reduce the impact of peak flows and ensure adequate summer low flows

- To reduce the deleterious impact of peak flows, institute impervious surface thresholds for the basin, retain 60% of the basin in forest cover, and encourage the use of innovative designs for permitted residential developments.
- Ensure road drainage is not routed into the stream network.
- Use the established minimum instream flow recommendation to condition future water applications. Prohibit additional surface water withdrawal or groundwater withdrawals that will diminish the recommended flow level.
- Institute water conservation programs, and investigate opportunities for reducing the number of shallow wells within the watershed.
- Require onsite infiltration of runoff from impervious surfaces where soils are appropriate.

Protect and restore riparian forests

- Continue acquisition efforts underway throughout the watershed through the efforts of the Hood Canal Salmon Sanctuary.
- Replant degraded riparian zones with appropriate native species.

- Review and adjust the Kitsap Critical Area Ordinance consistent with recommendations for riparian buffers.

Strength of Evaluation and Information Needs

Confidence in the evaluation is rated as high based on the extensive amount of habitat monitoring conducted by PNPTC, research at the UW, and long term escapement returns collected for the Big Beef watershed.

Additional information needed to better quantify the relationship between current conditions and summer chum distribution includes:

1. Instream flow monitoring of both summer flow periods and peak winter flows.
2. Channel assessments to determine the relationship between peak flows and channel forming events. It would be helpful to establish permanent channel cross sections and resurvey Madej's original cross sections.
3. Temperature monitoring extended into mid October to determine if elevated temperatures are a concern.
4. Completion of a sediment budget, including identification of the amount of sediment being actively contributed by destabilized banks and failing roads.

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Appendix Report 3.7
Riparian Assessment Methodology and Summary of Results

As part of the analysis of habitat limiting factors, aerial photo interpretation was employed to evaluate the condition of riparian forests along summer chum streams in Hood Canal and the eastern Strait of Juan de Fuca. Using 1997 Washington State Department of Natural Resources 1:12,000-scale aerial photos viewed in stereo, two trained analysts assessed the impacts to riparian zones in relation to adjacent land use. On the Dungeness River 1998, 1:6,000-scale photos were used. Segments with relatively homogenous riparian conditions and land use were delineated on each side of all stream channels within the current or known historic range of summer chum. For each segment the forested riparian buffer width, average stand diameter, species composition, and stand density were noted and the dominant, stream-adjacent land use recorded. We modified the methodology outlined under the Washington State Watershed Analysis Riparian Module to consider both riparian conditions and dominant land use within 200 feet of stream channels. Due to time constraints, the data was not field verified, and we did not assess stream channels upstream of the range of summer chum though downstream transport of large woody debris (LWD) is known to be an important recruitment source for in-channel LWD.

Each riparian segment was categorized according to forested buffer width, species composition, average stand diameter, and stand density. We resolved six buffer width categories: none, <33 ft, 33-66 ft, 66-99 ft, 99-132 ft, and 132-200 ft. Species composition categories included: conifer-dominated (>70% canopy coverage), deciduous-dominated (>70%), mixed conifer/deciduous (both <70%), and none. Tree canopy size and structure was used as a surrogate for average stand diameter: <12 in diameter at breast height (dbh), 12-20 dbh, and >20 dbh. Stand density was categorized as dense (<33% ground exposure), sparse (33-80% ground exposure), and extensively cleared (>80% ground exposure). It is important to note that our assessment of buffer width, species composition, average stand diameter, and stand density applied to only the stream-adjacent, forested portion of the 200 ft. riparian zone. We also categorized dominant land use outside this forested buffer (if any) and within the 200 ft. riparian zone. Land use categories included: forestry, agriculture, rural residential, urban/industrial, road/dike, and no land use (wetlands, protected areas). The road/dike land use class was used where stream-adjacent parallel roads or dikes were present because, though they were rarely dominant land uses within a segment on a per area basis, their impact on riparian forests was interpreted to supersede in importance other land uses within the segment. The forestry category included clearcut and recently replanted areas without canopy closure. Older managed forest stands often could not be readily distinguished from adjacent forested buffers and were included in the calculation of forested buffer. As a result, our estimates of permanent forested buffer areas are likely high and the estimated area under active forestry use likely low.

Thresholds were used to determine generalized summer chum habitat impact ratings (low=1, moderate=2, and high=3) from riparian forest condition for each variable (width, average stand

diameter, species composition, stand density; Appendix Table 3.7.1) by segment. Since no riparian forests within the range of summer chum exhibited old-growth or undisturbed conditions, we did not utilize a no impact rating. These thresholds were determined after considering the relative ability of riparian forests to provide critical shade and LWD-supply functions for stream channels used by summer chum. For example, the ability of a buffer to supply LWD over time is partly dependent upon buffer width. It has been calculated that a 50 ft no cut buffer will supply 32% of LWD at age 200, a 135 ft buffer 77% of LWD, and a 210 ft buffer 100% of LWD (T. Beechie, personal communication). Thus, buffers greater than 132 ft in width were considered low impact, 66-132 ft a moderate impact, and <66 ft in width high impact. The riparian forest buffer extent rating was computed as a composite of the scores for stand density and width; stand density scores were added to the buffer width scores, and if either or both scored as a high impact the riparian extent rating defaulted to high impact. Average stand diameter was used as a surrogate to rate riparian age in our overall matrix of habitat factors (see section 3.4.3.2, Table 3.17). Overall watershed-level riparian assessment ratings were then computed for riparian species composition, ageaverage stand diameter), and extent (Appendix Table 3.7.3) using all the riparian segments for a given stream weighted by their total *length*.

Table 3.7.1. Summary of riparian assessment impact categories. Low impact was rated a 1, moderate impact was rated 2, and high impact rated 3. The one exception was riparian buffer density, rated 0 for low impact, 1 for moderate impact, and 2 for high impact. Riparian buffer density was added to riparian buffer extent to calculate that rating.

Riparian assessment category	Low Impact	Moderate Impact	High Impact
Species composition	Conifer dominated (>70% of the canopy)	Mixed conifer/deciduous (both < 70%)	Deciduous dominated (>70% of the canopy) or no tree cover
Average stand diameter	>20 in dbh[1]	12-20 in dbh	<12 in dbh
Density	<33% ground exposure	33-80% ground exposure	>80% ground exposure
Width	>132 ft wide forested buffer	66-132 ft wide forested buffer	<66 ft wide forested buffer

[1] dbh, diameter at breast height

An example serves to illustrate how these impact ratings were calculated. In Snow Creek (Appendix Table 3.7.2) there is 4,400 ft. of mixed conifer and deciduous stands, no conifer-dominated stands, and 28,000 ft. of shrub/grass or deciduous-dominated forest. The weighted mean calculation for riparian species composition is thus: (4,400/32,400)*2+(28,000/32,400)*3 = 2.86.

Table 3.7.2. Calculation of weighted average rating. For Snow Creek, the weighted mean calculation was (4,400/32,400)*2+(28,000/32,400)*3 = 2.86.

Riparian species composition

Stream	Total Riparian Length	Mixed conifer and decid	Conifer dom (<70%)	Decid dom (>70%)	Shrub or grass	No riparian vegetation	Weighted mean rating
Snow	32,400	4,400	0	26,000	2,000	0	2.86

While the analysis of riparian buffer extent, age, and species composition was based on stream *length*, the analysis of riparian land use sought to quantify the *area* of the riparian zone occupied by various land uses. The "riparian zone" was defined as the area within 200 ft. of streams harboring

summer chum, from the mouth to the upper extent of their spawning distribution. We calculated the area under each land use and report percentages of the total riparian zone under each land use (Appendix Table 3.7.3-D).

Table A3.7.3. Summary of results for the riparian forest assessment. For the riparian buffer condition analysis, a rating of 2.5 to 3.0 was considered a high impact, 2.0-2.49 a moderate impact, <2.0 a low impact.

A. Riparian Forest Average Stand Diameter (Percent by Length)

Stream	Total Riparian Length (ft)	Small (<12 in dbh)	Medium (12-20 in dbh)	Large (>20 in dbh)	No buffer present	Weighted mean rating
Big Anderson	16,000	48%	52%	0%	0%	2.5
Big Beef	60,200	36%	64%	0%	0%	2.4
Big Mission	20,400	36%	64%	0%	0%	2.4
Big Quilcene	49,600	44%	48%	0%	8%	2.5
Chimacum	29,600	42%	42%	0%	16%	2.6
Dewatto	40,800	32%	68%	0%	0%	2.3
Dosewallips	45,800	51%	45%	0%	4%	2.6
Duckabush	32,200	32%	66%	0%	2%	2.4
Dungeness	104,200	44%	52%	0%	4%	2.5
Hamma Hamma	35,000	48%	45%	3%	4%	2.5
Jimmycomelately	18,800	34%	66%	0%	0%	2.3
Lilliwaup	5,800	0%	79%	0%	21%	2.2
Little Quilcene	29,800	70%	27%	0%	3%	2.7
Salmon	21,600	15%	63%	0%	22%	2.4
Seabeck	11,600	41%	59%	0%	0%	2.4
Skokomish	323,200	33%	48%	4%	16%	2.4
Snow	32,400	50%	44%	0%	6%	2.6
Stavis	4,800	0%	100%	0%	0%	2.0
Tahuya	96,800	24%	69%	0%	7%	2.3
Union	53,800	67%	33%	0%	0%	2.7

B. Riparian Forest Buffer Species Composition (Percent by Length)							
Stream	**Total Riparian Length (ft)**	**Mixed**	**Conifer**	**Decid**	**Shrub /grass**	**No riparian veg**	**Weighted mean rating**
Big Anderson	16,000	23%	0%	77%	0%	0%	2.8
Big Beef	60,200	47%	5%	48%	0%	0%	2.4
Big Mission	20,400	2%	0%	98%	0%	0%	3.0
Big Quilcene	49,600	11%	40%	41%	5%	3%	2.1
Chimacum	29,600	57%	0%	27%	16%	0%	2.4
Dewatto	40,800	96%	0%	4%	0%	0%	2.0
Dosewallips	45,800	52%	3%	41%	4%	0%	2.4
Duckabush	32,200	57%	18%	23%	0%	2%	2.1
Dungeness	104,200	66%	5%	25%	4%	0%	2.2
Hamma Hamma	35,000	22%	48%	26%	4%	0%	1.8
Jimmycomelately	18,800	15%	43%	42%	0%	0%	2.0
Lilliwaup	5,800	79%	0%	0%	21%	0%	2.2
Little Quilcene	29,800	42%	7%	48%	0%	3%	2.5
Salmon	21,600	63%	0%	15%	22%	0%	2.4
Seabeck	11,600	59%	0%	41%	0%	0%	2.4
Skokomish	323,200	25%	26%	33%	15%	2%	2.2
Snow	32,400	14%	0%	80%	6%	0%	2.9
Stavis	4,800	58%	0%	42%	0%	0%	2.4
Tahuya	96,800	37%	4%	52%	7%	0%	2.6
Union	53,800	4%	0%	96%	0%	0%	3.0

C. Riparian Forest Buffer Extent (Percent by Length)

Stream	Total Riparian Length (ft)	Low Impact (buffer >132 ft wide)	Medium Impact (buffer 66-132 ft wide)	High Impact (buffer sparse and/or <66 ft wide)	Weighted Mean Rating
Big Anderson	16,000	41%	0%	59%	2.2
Big Beef	60,200	76%	6%	18%	1.4
Big Mission	20,400	31%	24%	45%	2.1
Big Quilcene	49,600	53%	2%	45%	1.9
Chimacum	29,600	33%	26%	41%	2.1
Dewatto	40,800	69%	16%	15%	1.5
Dosewallips	45,800	58%	21%	21%	1.6
Duckabush	32,200	59%	25%	16%	1.6
Dungeness	104,200	32%	18%	50%	2.2
Hamma Hamma	35,000	58%	0%	42%	1.8
Jimmycomelately	18,800	0%	31%	69%	2.7
Lilliwaup	5,800	52%	0%	48%	2.0
Little Quilcene	29,800	3%	38%	60%	2.6
Salmon	21,600	8%	22%	70%	2.6
Seabeck	11,600	0%	0%	100%	3.0
Skokomish	323,200	45%	25%	35%	1.9
Snow	32,400	17%	7%	76%	2.6
Stavis	4,800	79%	0%	21%	1.4
Tahuya	96,800	44%	27%	29%	1.9
Union	53,800	27%	11%	62%	2.4

D. Riparian Land Use (Percent by Area)

Stream	Total Riparian Area (ft^2)	Forested buffer	No land use	Forestry	Agric	Rur resid	Urb/ Com	Road /
Big Anderson	3,200,000	55%	0%	0%	9%	0%	0%	36%
Big Beef	12,040,000	85%	0%	0%	0%	4%	4%	7%
Big Mission	4,080,000	70%	0%	0%	0%	17%	8%	5%
Big Quilcene	9,920,000	62%	0%	1%	10%	3%	3%	21%
Chimacum	5,920,000	51%	0%	0%	16%	17%	16%	0%
Dewatto	8,160,000	87%	0%	5%	2%	4%	0%	2%
Dosewallips	9,160,000	79%	2%	3%	3%	7%	6%	0%
Duckabush	6,440,000	74%	2%	0%	0%	9%	12%	3%
Dungeness	20,840,000	58%	0%	0%	9%	13%	0%	20%
Hamma Hamma	7,000,000	65%	0%	23%	10%	2%	0%	0%
Jimmycomelately	3,760,000	34%	0%	38%	12%	7%	0%	9%
Lilliwaup	1,160,000	52%	0%	0%	20%	0%	0%	28%
Little Quilcene	5,960,000	40%	2%	6%	33%	8%	0%	11%
Salmon	4,320,000	32%	0%	25%	43%	0%	0%	0%
Seabeck	2,320,000	33%	0%	0%	23%	21%	0%	23%
Skokomish	64,640,000	64%	1%	1%	26%	2%	2%	4%
Snow	6,480,000	42%	0%	7%	35%	5%	0%	11%
Stavis	960000	83%	0%	0%	17%	0%	0%	0%
Tahuya	19360000	71%	1%	6%	8%	12%	0%	2%
Union	10760000	52%	0%	2%	13%	30%	0%	3%

Appendix Report 3.8
Freshwater Habitat Data Summary and Analysis Criteria

Freshwater habitat data can be found for a number of streams in Hood Canal and the Straits of Juan de Fuca. Below is a summary of the available habitat data (Appendix Table 3.8.1), targets used to analyze the data (Appendix Table 3.8.2), and the channel condition data (Appendix Table 3.8.3). Temperature data was only used if it was a continuous thermograph (i.e. no spot sampling). Temperature graph data was visually examined during the workshops to determine if it exceeded 12EC. Fine sediment data was only considered if it was gathered with a McNeil core sampler; visual estimates of surface sediment are not accurate and were not considered.

Appendix Table 3.8.1. Watersheds with habitat data used in the assessment.

Watershed	Channel condition data	Temperature	Fine Sediment
Jimmycomelately	X		
Salmon	X		X
Snow	X		X
Little Quilcene	X		
Big Quilcene	X		
Duckabush	X		
Hamma Hamma	X		
Skokomish	x[1]	X	
Union	X		
Big Mission	X		
Tahuya	X	X	X
Dewatto	X	X	X
Big Anderson	X		
Stavis	X	X	
Big Beef	X	X	

[1] Skokomish watershed channel condition data is for Vance Creek only.

Appendix Table 3.8.2. Stream habitat targets for channel condition habitat factors. Large woody debris (LWD) is number of pieces/m of channel length[1], percent pools is the surface area occupied by pools [2,3], pool frequency is the number of channel widths per pool [2], and fine sediment is the percentage of fine sediment with a diameter <0.85mm [2].

Habitat factor targets	Channel width and gradient	No-Low impact	Mod. impact	High impact
LWD [1]	<15 m	>0.4	0.2-0.4	<0.2
Percent pools [2]	<15 m; 2%	>55%	40-55%	<40%
Percent pools [3]	>15 m	>50%	35-50%	<35%
Pool frequency[2]	<15 m; 2%	<2	2-4	> 4
Temperature [4]	all	<12 ºC	--	>12ºC
Fine sediment [2]	all	<12%	12-17%	>17%

[1] Montgomery et al. 1995
[2] WFPB1995
[3] Pess et al. 1998
[4] Bjorn and Reiser 1991

Appendix Table 3.8.3. Channel condition habitat data summary. USFS (US Forest Service) was collected using Hankin and Reeves survey methodology. PNPTC (Point No Point Treaty Council) and USFWS (US Fish and Wildlife Service) were collected using TFW ambient monitoring methodology. Pool frequency is the number of channel widths per pool.

Stream	Data source	Survey year	RM (rivermile)[1]	LWD pieces/m	Pool freq.	Percent pools
Jimmycomelately	USFS	1990	0-1.9	0.09	9.0	30%
Salmon	PNPTC	1992	0-1.3	0.06, 0.15 [2]	4.8	39
Snow	PNPTC	1993	0-3.6	0.07 [3]	5.7	47
Little Quilcene	PNPTC	1992	0-3.8	0.03, 0.1 [2]	5.3	32
Big Quilcene	PNPTC	1993	0.8-3.8	0.01, 0.16 [2]	5.1	31
Big Quilcene	USFS	1992	0-4.0	0.06	-[4]	20
Duckabush	USFWS	1992	0.2-2.3	sparse	-[5]	31
Hamma Hamma	USFWS	1996	0.5-1.8	0.13	-[5]	50
Johns Creek	USFWS	1996	0-1.8	0.06	-[5]	-[5]
Union	PNPTC	1993	0-6.7	0.22	5.9	63
Big Mission	PNPTC	1993	0-1.5	0.07	6.5	33
Tahuya	PNPTC	1994	4.0-9.0	0.04, 0.15 [2]	2.4	72
Dewatto	PNPTC	1994	3.0-3.5	0.09, 0.28 [2]	4.1	37
Big Anderson	USFWS	1993/4	0-1.8	0.30	1.7	51
Stavis	USFWS	1993/4	0-0.6	0.26	1.8	53
Big Beef	PNPTC	1993/4	0-6.3	0.17	2.4	46

[1] This is the surveyed portion of the channel that overlapped the summer chum range.
[2] For PNPTC data, LWD volumes are calculated using only single piece data and calculated using single pieces plus pieces in jams. For LWD jams, only the overall volume was measured and not the individual piece count. To convert volume to pieces, jam volume was divided by average single piece volume for each survey. Thus the incomplete packing of wood within jams was not accounted for and total LWD numbers are likely overestimated. It is presented as both single pieces, and the total of single pieces plus those in LWD jams.
[3] This number does not include pieces in LWD jams and should be considered a low estimate. Individual piece volumes were not available to calculate pieces per jam. However given field observations, had total LWD pieces been counted, the channel would still fall within the highly degraded category.
[4] Could not be calculated from the data. Channel width was measured as summer low flow width.
[5] Partial survey, did not collect this information.

References

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Montgomery, D.R., G.E. Grant, and K, Sullivan. 1995. Watershed analysis as a framework for implementing ecosystem management. Water Resources Bulletin 31:369-385.

Pess, G.R., B.D. Collins, M. Pollock, T.J. Beechie, S. Grigsby, and A. Haas. 1998. Historic and current factors that limit coho salmon (Oncorhynchus kisutch) in the Stillaguamish river basin, Washington state: implications for salmonid habitat protection and restoration. A report prepared for Snohomish County Department of Public Works – Surface Water Management Division and the Stillaguamish Tribe, Everett, WA. 40 p.

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Appendix Report 3.9
General Fishing Patterns, and Regulation Summary by Year, Fishery, and Fleet

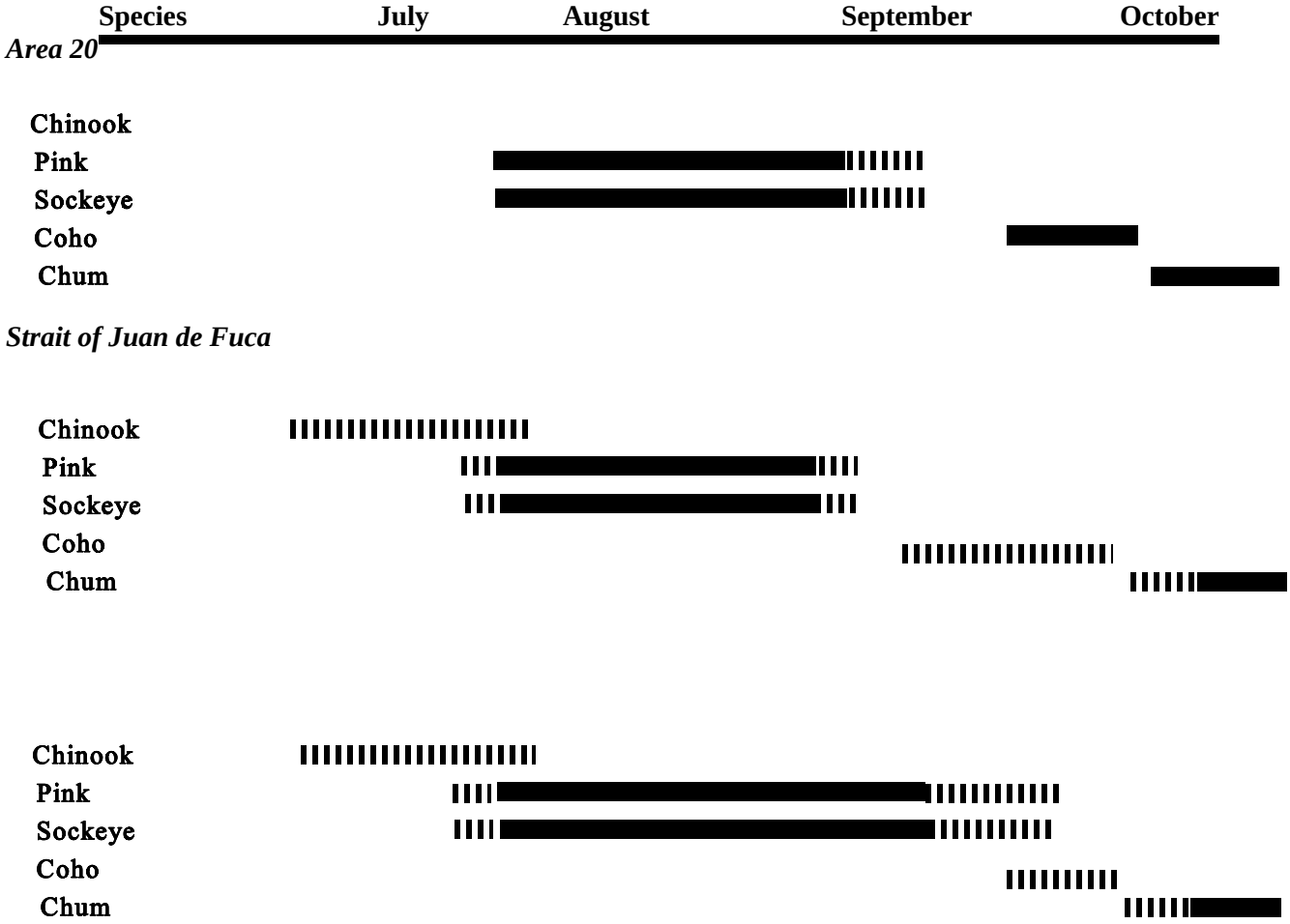
Introduction

The Harvest Management section (3.5) of the Summer Chum Salmon Conservation Initiative provides a narrative description of all fisheries that potentially can have some impact on Hood Canal and Strait of Juan de Fuca (HC-SJF) summer chum (see Part Three, section 3.5.3). This appendix report provides additional information specifically on commercial fishing patterns and regulations.

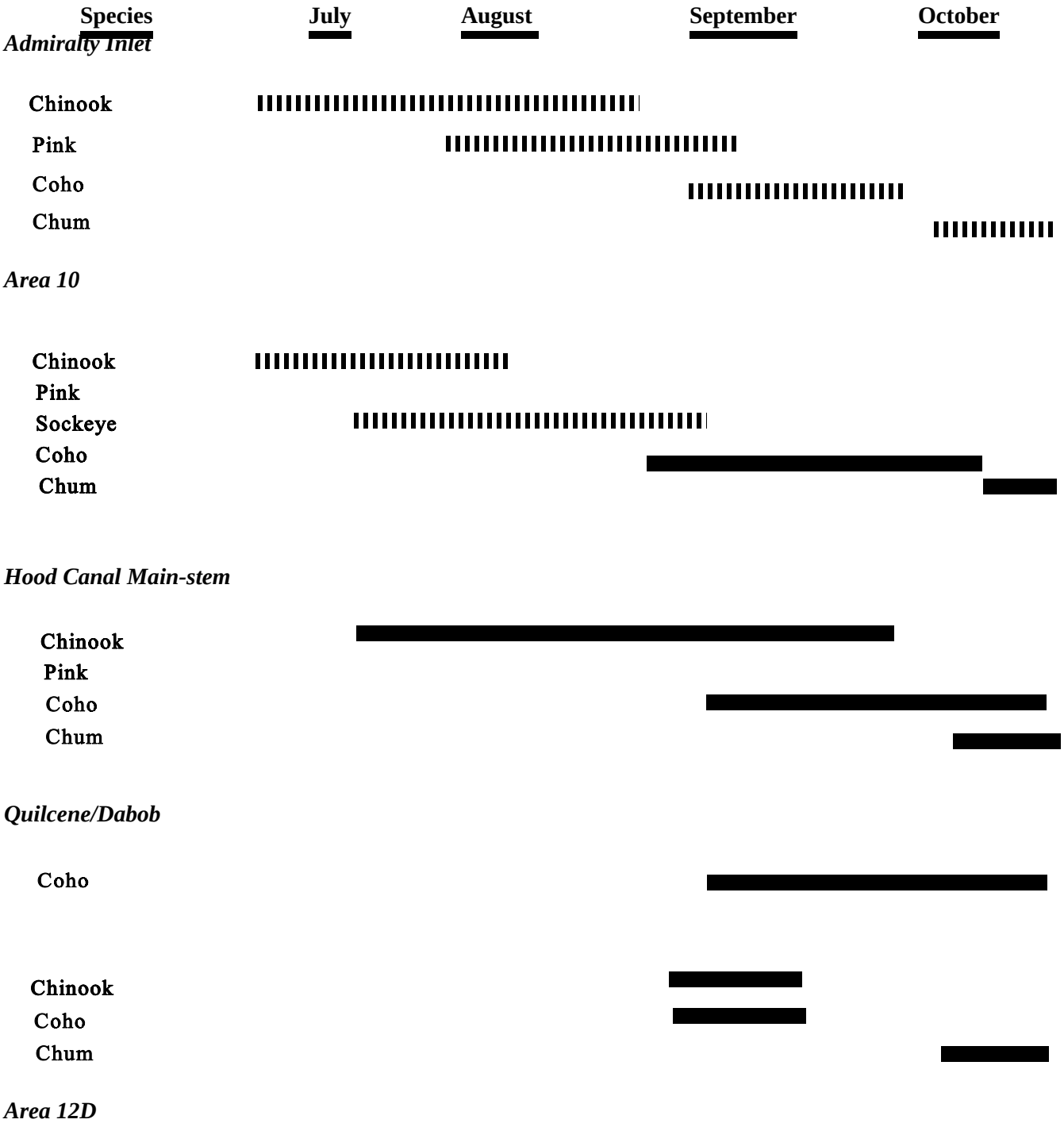
Appendix Figure 3.9.1 is a simple graphical depiction of the general pattern of commercial fishing in the major fishing areas impacting HC-SJF summer chum. The solid bars indicate some consistency in fishing pattern from year to year, and the dotted bars indicate a fishery that has been severely curtailed or eliminated in recent years or one that occurs very sporadically and with low effort or impact. For example, sockeye and pink salmon fisheries in the Strait of Juan de Fuca occur consistently every year (solid bar) and it is only the extremes of the timing of the fishery that changes much from year to year (dotted bar). The coho fishery in the Strait of Juan de Fuca used to occur with significant effort and catch, but has been severely constrained or eliminated in recent years (dotted bar). Commercial net fisheries for chinook in the Strait of Juan de Fuca used to be much more extensive, involving drift gill net gear. Now this fishery is very constrained, restricted to set gill net gear in near shore areas with very little effort and catch (dotted bar).

Detailed summaries of July through October net fishery openings in Hood Canal management units are provided in Appendix Tables 3.9.1 and 3.9.2 for treaty and non-treaty fishermen, respectively. These tables summarize regulations for the period from 1980 to 1997 and provide weekly summaries of the specific areas, gear types and number of days open.

Appendix Figure 3.9.1. General commercial fishing pattern by area, fleet and gear since the late 1970s (see text for explanation of dotted lines).



Appendix Figure 3.9.1 (continued)



Appendix Table 3.9.1. 1980-97 non-treaty openings for Hood Canal Mainstem Management Area (July through October). Gear Types: PS=purse seine, BS=beach seine, and GN=gillnet.

Year	Date(s)	Days	Marine Area	Gear Type
1980	10/21 - 10/28	2	12	PS, GN
1981	10/19 -10/19	1	12	PS, GN
1981	10/25 -10/25	1	12	GN
1981	10/26 -10/26	1	12	PS
1982	09/15 -09/15	1	12	GN
1982	09/16 -09/16	1	12	PS
1982	10/11 -10/11	1	12	GN
1982	10/12 -10/12	1	12	PS
1982	10/18 -10/18	1	12	PS, GN
1982	10/25 -10/26	1	12	GN
1982	10/26 -10/26	1	12	PS
1983	07/26 -07/26	1	12	GN
1983	08/01 -08/01	1	12	GN
1983	08/09 -08/09	1	12	GN
1983	08/15 -08/17	3	12	GN
1983	08/22 -08/24	3	12,12B	GN
1983	08/28 -09/01	S	12, 12B	GN
1983	09/11 -09/11	1	12	GN
1983	09/12 -09/12	1	12	PS
1983	09/19 -09/20	2	12	PS, GN
1983	09/25 -09/29	5	12	GN
1983	09/26 -09/30	5	12	PS
1983	10/03 -10/06	4	12,12A,12B	PS, GN
1983	10/09 -10/11	3	12,12A,12B	GN
1983	10/10 -10/12	3	12,12A,12B	PS
1983	10/17 -10/17	1	12	PS, GN
1983	10/23 -10/23	1	12	GN
1983	10/24 -10/24	1	12	PS
1983	10/31 -10/31	1	12	PS, GN
1984	07/30 -07/30	1	12,12B	GN
1984	07/31 -07/31	1	12,12B	PS
1984	08/07 -08/09	3	12,12B	PS, GN

Appendix Table 3.9.1 (continued). 1980-97 non-treaty openings for Hood Canal Mainstem Management Area (July through October). Gear Types: PS=purse seine, BS=beach seine, and GN=gillnet.

Year	Date(s)	Days	Marine Area	Gear Type
1984	08/13 -08/15	3	12,12B	PS, GN
1984	08/20 -08/22	3	12,12B	GN
1984	09/21 -08/23	3	12,12B	PS
1984	08/27 -08/29	3	12,12B,12C	PS, GN
1984	09/10 -09/11	2	12,12A	GN
1984	09/11 -09/12	2	12,12A	PS
1984	09/17 -09/19	3	12,12A,12B	PS, GN
1984	09/24 -09/24	1	12A	GN
1984	09/25 -09/25	1	12A	PS
1984	10/01 -10/01	1	12A	PS, GN
1984	10/08 -10/08	1	12A	GN
1984	10/09 -10/09	1	12A	PS
1984	10/15 -10/15	1	12,12A,12B	PS, GN
1984	10/15 -10/17	3	12A	PS, GN
1984	10/21 -10/21	1	12,12B	GN
1984	10/22 -10/22	1	12,12B	PS
1985	07/30 -07/30	1	12C	GN
1985	07/31 -07/31	1	12C	PS
1985	08/05 -08/07	3	12C	PS, GN
1985	08/13 -08/16	4	12C	PS
1985	08/18 -08/22	S	12B,L2C	GN
1985	08/19 -08/23	S	12C	PS
1985	08/25 -08/29	S	12B,L2C	GN
1985	08/26 -08/30	S	12C	PS
1985	09/02 -09/05	4	12B,12C	GN
1985	09/03 -09/06	4	12B,12C	PS
1985	09/09 -09/09	1	12,12A	GN
1985	09/10 -09/10	1	12,12A	PS
1995	09/16 -09/17	2	12,12A	PS, GN
1985	09/23 -09/25	3	12,12A	GN
1985	09/24 -09/26	3	12,12A	PS
1985	09/30 -10/03	4	12,12A	PS, GN

Appendix Table 3.9.1 (continued). 1980-97 non-treaty openings for Hood Canal Mainstem Management Area (July through October). Gear Types: PS=purse seine, BS=beach seine, and GN=gillnet.

Year	Date(s)	Days	Marine Area	Gear Type
1985	10/06 -10/10	5	12,12A,12B,12C	GN
1985	10/07 -10/11	S	12,12A,12B,12C	PS
1985	10/14-10/16	3	12,12A,12B,12C	PS, GN
1985	10/21 -10/21	1	12	GN
1985	10/22 -10/22	1	12	PS
1985	10/21 -10/23	3	12C	GN
1985	10/22 -10/24	3	12C	PS
1985	10/28 -10/28	1	12	PS, GN
1986	07/28 -07/31	4	12B,12C	PS, GN
1986	08/04 -08/07	4	12B,12C	GN
1986	08/05 -08/08	4	12B,12C	PS
1986	08/11-08/14	4	12B,12C	PS, GN
1986	08/18 -08/19	2	12B,12C	GN
1986	08/19 -08/20	2	12B,12C	PS
1986	08/25 -08/26	2	12,12B	PS, GN
1986	09/01 -09/03	3	12,12B	GN
1986	09/02 -09/04	3	12,12B	PS
1986	09/08 -09/09	2	12,12A,12B	PS, GN
1986	09/15 -09/16	2	12,12A,12B	GN
1986	09/16 -09/17	2	12,12A,12B	PS
1986	09/22 -09/24	3	12,12A,12B	PS, GN
1986	09/28 -09/30	3	12,12A,12B	GN
1986	09/29 -10/01	3	12,12A,12B	PS
1986	10/20 -10/20	1	12	GN
1986	10/21 -10/21	1	12	PS
1986	10/27 -10/27	1	12	PS, GN
1987	07/27 -07/30	4	12B,12C	GN
1987	07/28 -07/31	4	12C	PS
1987	08/03 -08/06	4	12B,12C	GN
1987	08/03 -08/06	4	12C	PS
1987	08/10 -08/13	4	12B,12C	GN
1987	08/11 -08/14	4	12C	PS

Appendix Table 3.9.1 (continued). 1980-97 non-treaty openings for Hood Canal Mainstem Management Area (July through October). Gear Types: PS=purse seine, BS=beach seine, and GN=gillnet.

Year	Date(s)	Days	Marine Area	Gear Type
1987	08/16 -08/19	4	12B,12C	GN
1987	08/17 -08/20	4	12C	PS
1987	09/14 -09/15	2	12,12A	PS, GN
1987	09/20 -09/22	3	12C	GN
1987	09/21 -09/23	3	12C	PS
1987	09/21 -09/22	2	12,12A	GN
1987	09/22 -09/23	2	12,12A	PS
1987	09/28 -09/29	2	12,12A,12C	PS, GN
1987	10/04 -10/04	1	12,1 2A,12B,12C	GN
1987	10/06 -10/05	1	12,12A,12B,12C	PS
1987	10/12 -10/13	2	12,12A,12B,12C	PS, GN
1987	10/19 -10/19	1	12,12B	GN
1987	10/20 -10/20	1	12,12B	PS
1987	10/19 -10/22	4	12A	GN
1987	10/20 -10/23	4	12A	PS
1987	10/26 -10/26	1	12,12B	PS, GN
1988	08/15 -08/16	2	12B,12C	PS, GN
1988	08/22 -08/23	2	12B,12C	GN
1988	08/23 -08/24	2	12B,12C	PS
1988	09/06 -09/07	2	12A	PS, GN
1988	09/12 -09/14	3	12A	GN
1988	09/13 -09/15	3	12A	PS
1988	09/19 -09/21	3	12A	PS, GN
1988	09/26 -09/27	2	12A	GN
1988	09/27 -09/28	2	12A	PS
1988	10/24 -10/25	2	12,12B	PS, GN
1988	10/31 -11/01	2	12,12B	GN
1989	07/24 -07/27	4	12B,12C	PS, GN
1989	07/31 -08/03	4	12B,12C	GN
1989	08/01 -08/04	4	12B,12C	PS
1989	08/07 -08/10	4	12B,12C	PS, GN
1989	08/14 -08/17	4	12B,12C	GN

Appendix Table 3.9.1 (continued). 1980-97 non-treaty openings for Hood Canal Mainstem Management Area (July through October). Gear Types: PS=purse seine, BS=beach seine, and GN=gillnet.

Year	Date(s)	Days	Marine Area	Gear Type
1989	08/15 -08/18	4	12B,12C	PS
1989	08/21 -08/24	4	12B,12C	PS, GN
1989	08/28 -08/31	4	12B,12C	GN
1989	08/29 -09/01	4	12B,12C	PS
1989	09/05 -09/08	4	12A,12B,12C	PS, GN
1989	09/11 -09/11	1	12,12B	GN
1989	09/11 -09/14	4	12A	GN
1989	09/12 -09/12	1	12,12B	PS
1989	09/12 -09/15	4	12A	PS
1989	09/18 -09/18	1	12,12B	PS, GN
1989	09/25 -09/26	2	12,12B	GN
1989	09/26 -09/27	2	12,12B	PS
1989	10/02 -10/03	2	12,12B	PS, GN
1989	10/09 -10/10	2	12,12B	GN
1989	10/10- 10/11	2	12,12B	PS
1989	10/16- 10/16	1	12,12B	GN
1989	10/17- 10/17	1	12,12B	PS
1989	10/23- 10/23	1	12,12B	PS, GN
1989	10/29- 10/30	2	12,12B	GN
1989	10/30- 10/31	2	12,12B	PS
1990	07/30- 08/02	4	12B,12C	PS, GN
1990	08/06- 08/09	4	12B,12C	GN
1990	08/07- 08/10	4	12B,12C	PS
1990	08/13- 08/16	4	12B,12C	PS, GN
1990	08/20- 08/23	4	12B,12C	GN
1990	08/21- 08/24	4	12B,12C	PS
1990	08/27- 08/30	4	12B,12C	PS, GN
1990	09/03- 09/06	4	12A,12B,12C	GN
1990	09/04- 09/07	4	12A,12B,12C	PS
1990	09/10- 09/10	1	12,12B	PS, GN
1990	09/10- 09/13	4	12A	PS, GN
1990	09/16- 09/21	5	12A	PS, GN

Appendix Table 3.9.1 (continued). 1980-97 non-treaty openings for Hood Canal Mainstem Management Area (July through October). Gear Types: PS=purse seine, BS=beach seine, and GN=gillnet.

Year	Date(s)	Days	Marine Area	Gear Type
1990	09/17- 09/18	2	12,12B	GN
1990	09/18- 09/19	2	12,12B	PS
1990	09/24- 09/25	2	12,12B	PS, GN
1990	10/01- 10/03	3	12,12B	GN
1990	10/02- 10/02	3	12,12B	PS
1990	10/08- 10/09	2	12,12A,12B	PS, GN
1990	10/15- 10/15	1	12,12A,12B	PS, GN
1990	10/22- 10/23	2	12,12B	GN
1990	10/23- 10/24	2	12,12B	PS
1990	10/29- 10/30	2	12,12B	PS, GN
1991	09/03- 09/06	4	12A	PS, GN
1991	09/09- 09/13	5	12A	PS, GN
1991	09/18- 09/20	S	12A	PS, GN
1991	09/23- 09/27	5	12A	PS, GN
1991	09/30- 10/04	5	12A	PS, GN
1991	10/16- 10/18	3	12A	PS, GN
1993	09/08- 09/10	3	12A	GN
1993	09/13- 09/16	4	12A	GN
1993	10/18- 10/19	2	12,12B	PS, GN
1993	10/25- 10/26	2	12,12B	PS, GN
1993	10/26- 10/27	2	12,12B	PS, GN
1994	10/31- 10/31	1	12B	GN
1995	10/30- 10/30	1	12,12B	PS, GN
1995	10/31- 10/31	1	12,12B	PS, GN
1998	09/23- 09/27	5	12A	BS
1996	09/30- 10/04	5	12A	BS
1996	10/07- 10/11	5	12A	BS
1997	09/03- 09/06	4	12A	BS
1997	09/08- 09/12	5	12A	BS
1997	09/15- 09/19	5	12A	BS
1997	09/22- 09/26	5	12A	BS
1997	09/29- 10/03	6	12A	BS

Appendix Table 3.9.1 (continued). 1980-97 non-treaty openings for Hood Canal Mainstem Management Area (July through October). Gear Types: PS=purse seine, BS=beach seine, and GN=gillnet.

Year	Date(s)	Days	Marine Area	Gear Type
1997	10/06- 10/10	5	12A	BS
1997	10/13- 10/17	5	12A	BS
1997	10/20- 10/21	2	12,12B	PS, GN
1997	10/27- 10/28	2	12,12B	PS, GN

Appendix Table 3.9.2. 1980-96 Treaty openings for Hood Canal Mainstem Management Area (July through October). Gear types: GN=gillnet, SN=set net, BS=beach seine, and HL=hook and line.

Year	Date (s)	Days	Area	Gear
1980	08/03 - 08/06	3	12	HL, SN, GN
1980	08/10 - 08/13	3	12	HL, SN, GN
1980	08/17 - 08/21	4	12	HL, SN, GN
1980	09/01 - 09/03	2	12	HL, SN, GN
1980	09/07 - 09/10	3	12,12B	SN, GN
1980	09/14 - 09/19	5	12,12C	SN, GN
1980	09/21 - 09/24	3	12,12B	SN, GN
1980	09/28 - 09/30	2	12,12C	SN, GN
1981	08/02 - 08/04	2	12,12C	HL, SN, GN
1981	08/09 - 08/12	3	12,12C	HL, SN, GN
1981	08/16 - 08/19	3	12,12C	HL, SN, GN
1981	08/23 - 08/25	2	12,12C	HL, SN, GN
1981	09/13 - 09/15	2	12	HL, SN, GN
1981	09/15 - 09/17	2	12,12B	HL, SN, GN
1981	09/20 - 09/22	2	12,12B	HL, SN, GN
1981	09/22 - 09/24	2	12,12C	HL, SN, GN
1981	09/27 - 09/30	3	12,12C	HL, SN, GN
1982	08/02 - 08/04	2	12	HL, SN, GN
1982	08/15 - 08/17	2	12	HL, SN, GN
1982	08/22 - 08/25	3	12	HL, SN, GN
1982	08/29 - 09/03	5	12	HL, SN, GN
1982	09/05 - 09/10	5	12	HL, SN, GN
1982	09/12 - 09/17	5	12,12C	HL, SN, GN
1982	09/18 - 09/23	5	12,12C	HL, SN, GN
1982	09/24 - 09/30	6	12,12C	HL, SN, GN
1983	08/01 - 08/03	2	12	HL, SN, GN
1983	08/07 - 08/10	3	12	HL, SN, GN
1983	08/14 - 08/18	4	12,12C	HL, SN, GN
1983	08/21 - 09/03	13	12,12C	HL, SN, GN
1983	09/03 - 09/08	5	12C	HL, SN, GN
1983	09/11 - 09/14	3	12,12B	HL, SN, GN
1983	09/16 - 09/18	2	12,12B	HL, SN, GN

Appendix Table 3.9.2 (continued). 1980-96 Treaty openings for Hood Canal Mainstem Management Area (July through October). Gear types: GN=gillnet, SN=set net, BS=beach seine, and HL=hook and line.

Year	Date (s)	Days	Area	Gear
1983	09/18 - 09/23	5	12,12C	HL, SN, GN
1983	09/25 - 09/30	5	12,12C	HL, SN, GN
1984	08/01 - 08/03	2	12,12C	HL, SN, GN
1984	08/05 - 08/10	5	12,12B	HL, SN, GN
1984	08/04 - 08/10	6	12C	HL, SN, GN
1984	08/12 - 08/17	5	12,12C	HL, SN, GN
1984	08/19 - 08/22	3	12,12C	HL, SN, GN
1984	09/03 - 09/05	2	12	HL, SN, GN
1984	09/09 - 09/14	5	12	HL, SN, GN
1984	09/16 - 09/21	5	12	HL, SN, GN
1984	09/17 - 09/20	3	12B	HL, SN, GN
1984	09/21 - 09/26	5	12	HL, SN, GN
1985	08/01 - 08/02	1	12,12B	HL, SN, GN
1985	08/04 - 08/09	5	12,12C	HL, SN, GN
1985	08/11 - 08/16	5	12,12C	HL, SN, GN
1985	08/18 - 08/21	3	12,12C	HL, SN, GN
1985	08/25 - 08/28	3	12,12C	HL, SN, GN
1985	09/02 - 09/04	2	12,12C	HL, SN, GN
1985	09/08 - 09/11	3	12,12B	HL, SN, GN
1985	09/15 - 09/28	13	12,12B	HL, SN, GN
1985	09/21 - 09/24	3	12C	HL, SN, GN
1985	09/29 - 09/30	1	12C	HL, SN, GN
1986	08/01 - 08/01	1	12,12C	HL, SN, GN
1986	08/04 - 08/08	4	12,12C	HL, SN, GN
1986	08/10 - 08/15	5	12,12C	HL, SN, GN
1986	08/17 - 08/20	3	12,12C	HL, SN, GN
1986	08/24 - 08/26	2	12,12B	HL, SN, GN
1986	09/07 - 09/11	4	12,12B	HL, SN, GN
1986	09/14 - 09/19	5	12,12B	HL, SN, GN
1986	09/21 - 09/26	5	12,12C	HL, SN, GN
1986	09/26 - 09/30	4	12,12C	HL, SN, GN
1987	08/02 - 08/07	5	12,12C	HL, SN, GN

Appendix Table 3.9.2 (continued). 1980-96 Treaty openings for Hood Canal Mainstem Management Area (July through October). Gear types: GN=gillnet, SN=set net, BS=beach seine, and HL=hook and line.

Year	Date (s)	Days	Area	Gear
1987	08/09 - 08/14	5	12,12C	BS, HL, SN, GN
1987	08/12 - 08/14	2	12C	HL, SN, GN
1987	08/16 - 08/21	5	12,12C	BS
1987	08/19 - 08/21	1	12C	HL, SN, GN
1987	08/20 - 09/05	16	12,12C	BS
1987	08/21 - 08/21	1	12C	HL, SN, GN
1987	09/06 - 09/11	5	12	BS, HL, SN, GN
1987	09/13 - 09/18	5	12,12B	BS, HL, SN, GN
1987	09/20 - 09/25	5	12,12C	HL, SN, GN
1987	09/27 - 09/30	3	12,12C	HL, SN, GN
1988	08/01 - 08/05	4	12,12C	HL, SN, GN
1988	08/07 - 08/13	6	12,12C	HL, SN, GN
1988	08/14 - 08/19	5	12,12C	HL, SN, GN
1988	09/25 - 09/28	3	12	HL, SN, GN
1989	08/01 - 08/04	3	12,12C	HL, SN, GN
1989	08/06 - 08/11	5	12,12C	HL, SN, GN
1989	08/13 - 08/18	5	12,12C	HL, SN, GN
1989	08/20 - 08/25	5	12,12C	HL, SN, GN
1989	08/27 - 09/01	5	12,12C	HL, SN, GN
1989	09/03 - 09/09	6	12,12C	HL, SN, GN
1989	09/10 - 09/13	3	12,12C	HL, SN, GN
1989	09/14 - 09/17	3	12C	HL, SN, GN
1989	09/17 - 09/21	4	12,12B	BS, HL, SN, GN
1989	09/17 - 09/21	4	12C	HL, SN, GN
1989	09/24 - 09/29	5	12,12C	HL, SN, GN
1990	08/01 - 08/04	3	12,12C	HL, SN, GN
1990	08/05 - 08/11	6	12,12C	HL, SN, GN
1990	08/12 - 08/18	6	12,12C	HL, SN, GN
1990	08/19 - 08/25	6	12,12C	HL, SN, GN
1990	08/26 - 09/01	6	12,12C	HL, SN, GN
1990	09/02 - 09/08	6	12,12C	HL, SN, GN
1990	09/10 - 09/14	4	12,12C	HL, SN, GN

Appendix Table 3.9.2 (continued). 1980-96 Treaty openings for Hood Canal Mainstem Management Area (July through October). Gear types: GN=gillnet, SN=set net, BS=beach seine, and HL=hook and line.

Year	Date (s)	Days	Area	Gear
1990	09/16 - 09/21	5	12,12C	HL, SN, GN
1990	09/23 - 09/28	5	12,12C	HL, SN, GN
1990	09/30 - 09/30	1	12,12C	HL, SN, GN
1991	08/01 - 08/03	2	12,12C	HL, SN, GN
1991	08/04 - 08/10	6	12,12C	HL, SN, GN
1991	08/11 - 08/17	6	12,12C	HL, SN, GN
1991	08/18 - 08/24	6	12,12C	HL, SN, GN
1991	08/25 - 08/31	6	12,12D	HL, SN, GN
1991	09/01 - 09/07	6	12,12D	HL, SN, GN
1992	08/01 - 08/01	1	12,12C	HL, SN, GN
1992	08/02 - 08/08	6	12,12C	HL, SN, GN
1992	08/09 - 08/15	6	12,12C	HL, SN, GN
1992	08/15 - 08/23	8	12,12C	HL, SN, GN
1992	08/23 - 08/30	7	12,12C	HL, SN, GN
1992	08/30 - 09/05	6	12,12C	HL, SN, GN
1993	08/01 - 08/08	7	12,12C	HL, SN, GN
1993	08/08 - 08/15	7	12,12C	HL, SN, GN
1993	08/15 - 08/22	7	12,12C	HL, SN, GN
1993	08/22 - 08/29	7	12,12C	HL, SN, GN
1993	08/29 - 09/05	7	12C	HL, SN, GN
1994	08/07 - 08/11	4	12,12C	HL, SN, GN
1994	08/14 - 08/18	4	12,12C	HL, SN, GN
1994	08/21 - 08/25	4	12C	HL, SN, GN
1995	08/01 - 08/03	2	12C	BS, HL