Supplementation Standards for Recovering ESA-listed Threatened Summer-Run Chum Salmon Populations in the Hood Canal and Strait of Juan de Fuca Regions of Washington

Tim J. Tynan
Sustainable Fisheries Division, NOAA Fisheries, 510 Desmond Drive, Suite 103, Lacey, WA 98503
email: tim.tynan@noaa.gov telephone: 360/753-9579

Chris Weller
Point No Point Treaty Council, 7999 NE Salish Lane, Kingston, WA 98346
email: cweller@silverlink.net telephone: 360/297-3422

Thom H. Johnson
Fish Program, Washington Department of Fish and Wildlife, 283286 Highway 101, Port Townsend, WA 98368
email: johnsthj@dfw.wa.gov telephone: 360/765-3979

Abstract

The Washington Department of Fish and Wildlife, the Point No Point Treaty Tribes and the U.S. Fish and Wildlife Service identified standards defining when and how to use artificial propagation for supplementing and reintroducing depleted summer chum salmon populations in the Hood Canal and Strait of Juan de Fuca regions of Washington State. The standards were developed and set forth in the *Summer Chum Salmon Conservation Initiative*[1], a joint resource management plan that defined a comprehensive strategy for recovering summer chum salmon to healthy self-sustaining levels. Following objectives guiding when supplementation and reintroduction would be applied, a decision process was assembled and implemented to select candidate summer chum stock projects. Projects were selected based on an assessment of stock extinction risk status, and an evaluation of potential benefits and risks associated with any proposed projects. Rigorous standards were developed to guide how selected supplementation and reintroduction projects are implemented. Cornerstone standards included limitation on the duration of all projects to 12 years, identification of populations not subject to supplementation as reference stocks, and identification of criteria for adjusting a project, or reducing or terminating it sooner than 12 years. Strategies for minimizing the risk of potential deleterious demographic, ecological, and genetic effects on natural and artificially propagated summer chum salmon were also defined to direct how supplementation would be applied. Monitoring, evaluation, and reporting requirements were also included as standards to allow for tracking of project performance and effects, and to guide program adjustments to ensure that the projects conformed with their objectives.

Introduction

Responding to severe declines in the abundance and distribution of indigenous Hood Canal and Strait of Juan de Fuca region summer-run chum salmon in the 1980s, the Washington Department of Fish and Wildlife, the Point No Point Treaty Tribes and the U.S. Fish and Wildlife Service developed a resource management plan to preserve and recover remaining

---

[1] The *Summer Chum Salmon Conservation Initiative* is available for review through the Washington Department of Fish and Wildlife's web-site - http://wdfw.wa.gov/fish/chum/chum.htm

stocks. Titled the *Summer Chum Salmon Conservation Initiative* (*SCSCI* - WDFW and PNPTT 2000), the plan identified the status of regional stocks, factors for their decline, and artificial propagation, habitat, and fisheries harvest management measures that were necessary to recover summer chum salmon in the region to healthy self-sustaining levels.

Included in the SCSCI are rigorous standards that determine when and how hatchery supplementation will be applied as a recovery action. Based on the best scientific data and the collective salmon management experience of the plan authors, these standards were developed with the goal of using artificial propagation to preserve and expeditiously recover extant summer chum salmon populations, and re-establish returns where stocks have been extirpated, while minimizing the risk of deleterious genetic, ecological, and demographic effects to supplemented and un-supplemented stocks. Of particular value was the experience gained during a very successful supplementation program for south Puget Sound wild summer chum stocks conducted from 1976 to 1991 (see Ames and Adicks 2003, this volume).

An over-riding understanding is that supplementation will be applied while other factors causing decreased summer chum abundances are addressed. This approach recognizes that supplementation measures alone will not lead to self-sustainability, or to the recovery of the ESA-listed summer chum populations. Commensurate, timely improvements in the condition of habitat critical for summer chum salmon survival, and implementation of protective harvest management measures, are also necessary to recover the listed populations to healthy levels.

The indigenous summer-run chum salmon populations that are the subject of recovery actions proposed in the SCSCI are listed as “threatened” under the Endangered Species Act (ESA) of 1973 (March 25, 1999; 64 FR 14508). As the Federal agency over-seeing protection of anadromous salmon under the ESA, NOAA Fisheries issued a final ESA 4(d) Rule applying prohibitions enumerated in section 9(a)(1) to protect the populations in January, 2001 (July 10, 2000; 65 FR 42422). Within the final 4(d) Rule, NOAA Fisheries did not find it necessary and advisable to apply ESA protective prohibitions to specified categories of activities that contribute to conserving listed salmonids or are governed by a program that adequately limits impacts on listed salmonids. Among these excepted categories are activities associated with artificial propagation programs, provided that a state or Federal Hatchery and Genetics Management Plan (HGMP) for the program has been approved by NOAA Fisheries as meeting criteria specified in the ESA 4(d) Rule. Supplementation standards from the SCSCI were carried forward in HGMPs assembled for eight individual summer chum stock supplementation and stock reintroduction programs. In March, 2002, NOAA Fisheries endorsed these artificial propagation components of the SCSCI by determining through ESA review that they were adequately conservative to prevent harm to the summer chum populations, and were likely to be beneficial to their recovery.

Active supplementation of selected Hood Canal and Strait of Juan de Fuca summer chum stocks began in 1992, operating concurrently with the development of the principles contained in the SCSCI. From an initial start in 1992 with two stocks at high risk of extinction, supplementation efforts are now contributing to increased returns to five of the eight extant stocks, and reintroduction projects are returning fish to two streams that once contained summer chum salmon (see Johnson and Weller, 2003, this volume).

Following is an overview of guiding standards from the SCSCI that were endorsed under the ESA by NOAA Fisheries, defining when and how to supplement summer chum salmon populations to meet stock recovery, restoration, and listed wild stock protection objectives.

Standards Guiding *When* to Supplement or Reintroduce

By the early 1990s, summer chum salmon populations in the regions were assessed as being at a high risk of extinction and at least four populations had been extirpated. Total spawner escapement had declined to under 1,000 fish, and several populations escaped under 25 fish in consecutive years. The resource co-managers (WDFW and the Point No Point Treaty Tribes) determined that immediate action was required, and supplementation and reintroduction projects were initiated, with commensurate control of negative fisheries harvest and habitat degradation factors, to expeditiously preserve and restore the populations. The overarching standards that guided selection of populations, and when to supplement or reintroduce were that supplementation should only be done to rebuild a population when the population is at risk or extinction, or to develop a broodstock for reintroduction; and supplementation and reintroduction should occur only as part of a comprehensive effort to understand and effectively address factors for decline or extirpation of a population. Following these standards, a decision framework was developed and applied to assess supplementation and reintroduction options relative to SCSCI objectives, provide a strategy for prioritizing potential actions, and for defining the basis for decisions in a transparent manner. The objectives applied in the decision process for developing supplementation and reintroduction projects were:

- *to rebuild summer chum salmon populations at risk of extinction*;
- *to restore summer chum salmon to streams where a viable spawning population no longer exists;*
- *to maintain or increase summer chum salmon populations of selected streams to a level that will allow their use as broodstock donors for streams where the summer chum populations has been lost; and,*
- *to avoid and reduce the risk of deleterious genetic and ecological effects.*

The initial part of the decision process for selecting projects involved general evaluation of existing and recently extinct summer chum stocks as candidates, considering several factors affecting benefits and risks. Candidate stocks were then subjected to more focused assessments of potential risk from hatchery failure, ecological hazards, and genetic hazards. Based on the general evaluation, and the subsequent assessments of risk, a list of selected supplementation and reintroduction projects was generated. Included were existing projects, assuming wild population statuses that existed prior to adult returns from the projects. This selection and risk/benefit determination process is generally described as follows.

In selecting and ranking projects for supplementation or reintroduction, a number of factors bearing on need, urgency, and practicality were considered. These factors included extinction risk ratings for candidate supplementation stocks (based on mean escapement levels and recent population trends); potential population size (reflecting on the magnitude of the stock's historical production relative to the historical overall production in the region); knowledge of the habitat-related factors affecting the stock, and what, if any, habitat recovery actions are on-going or planned; availability of broodstock for the candidate supplementation or reintroduction action; and available resources to implement the action. These factors were rated for each extant and recently extirpated stock. Ranges of rating scores reflected the relative importance of each factor. Details for the rating approach are provided on pages 134 and 135 of the SCSCI. The rating process led to the ranking of candidate summer chum salmon stocks for supplementation or reintroduction.

In furtherance of this selection process, summer chum salmon populations identified as candidates for supplementation or reintroduction were subject to risk and benefit assessments. The purpose of these stock-by-stock assessments was to help determine whether potential benefits of a project, if implemented, outweighed potential deleterious effects. Outlines and characterizations of potential benefits and hazards of supplementation developed by Waples (1996) and Cuenco *et al.* (1993) were incorporated into the assessment framework to indicate parameters that should be considered in the context of a stock recovery program. Benefits and hazards identified in these documents were applied to objectively weigh and consider the appropriateness of a proposed supplementation program. Lists of potential benefits provided in the documents were augmented by specific benefits anticipated for summer chum salmon populations in the region, and positive results of supplementation already in hand. Benefits considered in the project assessment process, and their assumed, supportive rationale, included:

- *Reduce short term extinction risk.* Supplementation may be used to reduce the risk that a population on the verge of extirpation will be lost by expeditiously boosting the number of emigrating juveniles in a given brood year.
- *Preserve population while factors for decline are being addressed.* Supplementation may be used to preserve or increase summer chum salmon populations while other factors causing decreased abundances are addressed.
- *Speed recovery.* Supplementation may be used to accelerate recovery of populations by increasing abundances in a shorter time frame than may be achievable through natural production.
- *Establish a reserve population for use if the natural population suffers a catastrophic loss.* Supplementation programs may be used to create an additional reservoir for a particular summer chum genome to prevent loss of the entire population due to natural or anthropogenic catastrophes.
- *Reseed vacant habitat capable of supporting salmon.* Summer chum salmon may be reintroduced to streams where populations have been extirpated and the causes of extirpation are being addressed.
- *Provide scientific information regarding the use of supplementation in conserving natural populations.* Valuable information indicating the effectiveness and effects of supplementation in recovering summer chum salmon can be collected.

Potential hazards to targeted and non-supplemented natural populations that may result from a supplementation or reintroduction program were also assessed. These hazards included:

- Partial or total hatchery failure (potential for catastrophic loss of propagated stock);
- Ecological impacts to natural-origin summer chum through predation, competition, and disease transfer;
- Genetic effects to the propagated and unsupplemented populations (within and among population diversity reduction);
- Donor stock risks (e.g., numerical reduction or selection effects through broodstock collection); and
- Risks to other salmonid populations and species (e.g., redd superimposition impacts on wild pink salmon).

For each candidate supplementation and reintroduction project, each of the above hazards was weighed in terms of its consequence to natural origin populations. This assessment assumed compliance with guidelines, operating criteria, and monitoring measures in the SCSCI to mitigate and/or minimize the effects of each hazard. Determining the likelihood of each hazard was accomplished by considering specific criteria defining effective means (based on the best scientific information or the judgement of experts) for avoiding or minimizing occurrence of the particular hazard. These criteria are identified in Table 3.5 of the SCSCI. A judgement was made in each instance regarding the probability of success (low, moderate, or high) that each criterion will be met, given the SCSCI's risk aversion guidelines. Results of this hazard risk assessment procedure were incorporated into the final consideration of each project, leading to the final selection of projects. For selected projects, compliance with risk avoidance or minimization criteria used in the assessment process is continuously tracked. Failure to meet criteria defined for each hazard results in application of adaptive management actions. These actions are applied to determine why project objectives are not being met, and then, what changes will be applied in procedure or protocol to ensure that the objective is met in the future.

The outcome of the candidate summer chum population selection process was the identification of stocks selected for supplementation or reintroduction, stocks not recommended for intervention at the present time, pending further assessment, and stocks not recommended for supplementation or reintroduction under the SCSCI.

Standards Guiding When to Modify or Stop a Supplementation or Reintroduction Program

Standards applied to determine when supplementation and reintroduction programs will be modified or terminated were also defined in the SCSCI. By definition, supplementation and reintroduction were proposed to be used as much as possible as short term means to preserve, rebuild, or restore a naturally producing summer chum salmon population through the use of artificial propagation. One intent is to limit the duration of the programs to minimize the risk that adverse effects on the natural-origin population result from the use of artificial propagation. This intent is balanced by the need to allow the program to progress for a sufficient duration of time to allow the target population for rebuilding or reintroduction to be sufficiently recovered or established. Also, as the program progresses there should be an allowance for adequate evaluation of whether the program is effective, and for adaptive management of the program as a result of evaluation findings.

An adaptive management approach was selected in the SCSCI for defining when a supplementation or reintroduction program should be modified or terminated. The selected method combined genetic impact reduction and numerical return goal approaches with the tenets of adaptive management. Included in the approach were decision factors that may be applied as the program progresses, and as data from the program are collected, to allow adjustment of a program (e.g., reducing juvenile hatchery fish release numbers as the number of natural-origin recruits increases), or termination sooner than defined through genetic or numerically-based elements. The approach is generally consistent with factors presented within Hard *et al.* (1992) that indicate parameters to be considered in assessing the utility of a supplementation program. The following six standards were developed and included in the SCSCI to determine when a supplementation or reintroduction program should be terminated or modified.

1) The maximum duration of regional summer chum salmon supplementation programs will be based on criteria that minimize the likelihood that potentially deleterious genetic changes occur in the wild population.

This objective is met by applying a three generation maximum duration (12 years) for all summer chum salmon supplementation programs. Geneticists working with the co-managers advised that a three generation maximum duration limits the risk of adverse within and among population diversity reduction effects that could harm the target or conspecific wild populations (S. Phelps, WDFW, pers. comm., April, 1998). This limit also provides two generations (eight years) of adult returns to assess the program, prior to cessation of egg takes. An exception to this duration limit, leading to an increase in the duration of a program, may be acceptable if there have been catastrophic declines in habitat condition, or if other uncontrollable factors affecting summer chum survival emerge during the course of a supplementation effort, making sustainable natural production unlikely. In such a situation, the risk of continuing the project would be re-evaluated and measured against jeopardy to the status of the target stock that is likely if the program were terminated. Extension of a project longer than three generations necessitates compliance with more rigorous genetic hazard reduction criteria included in the SCSCI.

2) If adult return targets are met before the three generation maximum limit is reached, then the program may be reconsidered, and may be reduced or terminated.

Adult return targets defined specifically for each project were based on the magnitude of total adult escapements to consider program reductions, and on escapement of only natural origin recruits resulting from supplementation program and wild-origin fish to consider program termination. Program reduction or cessation determinations may therefore be made as follows:

- When the total summer chum salmon adult escapement meets or exceeds 1974-78 average escapement for the stock for four consecutive years, the desired number of juvenile hatchery-origin fish produced for the program will be reduced, after considering circumstances bearing on the sustainability of the population.
- When the total number of natural origin recruits escaping to the production stream resulting from the supplementation program and wild-origin fish meets or exceeds 1974-78 average escapement for the stock for four consecutive brood years, the supplementation program may be terminated.
- When the adult return target used to indicate when a supplementation program

should be reduced or terminated is based on another number that will assume precedence over 1974-78-derived goals.

3) ***Supplementation and reintroduction programs may be terminated if they are no longer believed to be necessary for timely recovery, for reasons other than the success of supplementation or reintroduction, including improvements in ocean survival or habitat condition.***
4) ***Supplementation programs will be modified or terminated if appreciable genetic or ecological differences between hatchery and wild fish have emerged during the recovery programs.***
5) ***Supplementation programs will be modified or terminated if there is evidence that the programs are impeding recovery.***
6) ***Supplementation or reintroduction programs will be modified or terminated if there is evidence that the programs are negatively impacting a non-target ESA-listed salmonid population.***

Standards Guiding *How* to Supplement or Reintroduce

General and specific guiding principles describing how supplementation and reintroduction programs will be conducted were included in the SCSCI. These principles were applied to help address risks to natural origin fish, and to ensure the effectiveness of supplementation and reintroduction programs selected for implementation through the aforementioned risk/benefit assessment framework. General standards guiding how to supplement or reintroduce are summarized below. A presentation of specific criteria, expanding on these general guidelines, is included in Appendix Report 3.1 of the SCSCI.

An overarching strategy guiding how projects will be conducted is the phased implementation of individual and regional programs, rather than commencing selected programs at maximum levels. This strategy, including step-wise initiation of supplementation programs within the region or the initial release of lower than goal numbers of supplemented fish into a specific watershed, allows for assessment of initial effects of each program in achieving goals, while minimizing risks to wild summer chum populations. An additional overarching strategy is selection and maintenance of non-supplemented wild summer chum populations that comprise a representative spectrum of existing diversity. These populations will be maintained in a natural state without assistance of supplementation to act as reference populations for tracking effects and benefits of supplementation programs implemented in adjacent watersheds. The stronger unsupplemented wild populations may still be used as donor stocks (subject to risk assessments applied for all candidate programs) to reintroduce summer chum into watersheds where the original population has been extirpated to help maintain population diversity in the region.

Standards addressing individual hatchery hazards scoped in the project assessment process were developed to minimize, when applied, potentially adverse effects on wild populations that may result from supplementation programs. Strategies described in Busack and Currens (1995), Cuenco *et al.* (1993), Kapuscinski and Miller (1993), Waples (1996) and Hard *et al.* (1992) were adapted by co-manager staff with knowledge and long-term experience regarding chum salmon hatchery propagation, life history, and hatchery effects to define risk aversion and minimization methods addressing each hazard category. Following are hazards addressed and key strategies applied to minimize the risk of their occurrence.

- **Partial/total hatchery failure**. Catastrophic loss of summer chum under propagation in a hatchery may occur as a result of dewatering due to power failure or screen fouling, flooding, or poor fish cultural practices. A key method for reducing the risk of catastrophic loss to a supplemented population is propagation of the population at more than one location (including for the purposes of reintroduction). By spreading the risk across programs, the likelihood that the genome will be retained in the event of catastrophic loss at one facility is increased. Other risk reduction methods under this category for hatcheries propagating summer chum included hatchery siting guidelines, emergency response strategies, and back-up hatchery equipment needs.
- **Predation.** The risk of direct predation effects to wild summer chum salmon resulting from the supplementation programs is low, due to the small (1 gram; 53 mm fl) average size of summer chum salmon released through the programs. Indirect predation effects co-occurring wild summer chum potentially posed by the attraction of avian and fish predators to hatchery-origin fish releases are also unlikely. The risk of indirect predation effects is mitigated by juvenile release levels from each program that are small in magnitude (less than 500,000 fed fry per year) relative to the size of the area into which the fish are released (Hood Canal or Strait of Juan de Fuca marine waters), rapid emigration of hatchery fish through freshwater “bottleneck” areas, and likely divergent migratory areas between the hatchery and smaller wild-origin summer chum fry.
- **Competition.** The risk that hatchery program origin summer chum will compete with wild summer chum fry for food is minimized through the release of hatchery fish (53 mm fl) that are larger in size than the wild fry (39 - 41 mm fl). The larger hatchery fish are likely to prey on pelagic rather than epibenthic organisms, and will emigrate and forage in different estuarine realms (offshore) than wild fry, which initially emigrate in very shallow nearshore areas.
- **Disease.** All supplementation and reintroduction projects will apply Pacific Northwest Fish Health Protection Committee (PNFHPC 1989) and Salmonid Disease Control Policy of the Fisheries Co-managers of Washington State (NWIFC and WDFW 1998). These guidelines define rearing, sanitation, and fish health practices that minimize the incidence of disease outbreaks in propagated populations, thereby decreasing the risk of fish pathogen amplification and transmission to co-occurring wild summer chum populations. All hatchery summer chum salmon populations will be inspected by WDFW or USFWS fish pathologists to certify their disease status and health condition prior to release.
- **Loss of genetic variability between populations**. An objective of the SCSCI is to maintain existing genetic diversity among the region’s summer chum populations. Diversity-based management measures will be implemented in all programs to minimize the likelihood for outbreeding depression and potential negative effects on wild stock fitness. Key standards are:
    - supplementation programs for streams selected under the plan will propagate and release only the indigenous population;
    - transfers of each donor stock for reintroduction will be limited to only one target

  - watershed outside of the range of the donor stock to avoid the situation that one or few stocks within the region predominate;
  - supplemented and reintroduced populations will be acclimated to the watershed desired for outplanting to ensure that the summer chum retain a high fidelity to the targeted stream;
  - for reintroduced populations, where feasible, local adaptation should be fostered by using returning spawners rather than the original donor population as broodstock if the reintroduction is still in progress; and,
  - all summer chum produced in hatchery programs will be marked to allow for monitoring and evaluation of adult returns.
- **Loss of genetic variability within populations.** Standards were also developed to reduce the risk that within population genetic variability would be lost as a result of inbreeding depression, genetic drift, or domestication selection. Within population diversity loss risk reduction measures included:
  - limitation of the duration of all supplementation programs to a maximum of three chum salmon generations (12 years) to minimize the likelihood for divergence between hatchery broodstocks and target natural stocks;
  - collection of broodstock so that they represent an unbiased sample of the naturally spawning donor population with respect to run timing, size, age, sex ratio, and any other traits identified as important for long term fitness;
  - use of returning adults produced by a supplementation program, with natural-origin fish, as broodstock over the duration of the program as a measure to increase the effective breeding population size;
  - application of spawning protocols will be applied to ensure that hatchery broodstocks are representative of wild stock diversity. These measures include spawning of broodstock proportionately across the breadth of the natural return, randomizing matings with respect to size and phenotypic traits, application of factorial, or at least 1 : 1 male-female mating schemes, and avoidance of intentional selection for any life history or morphological trait. Spawning protocols will equalize as much as possible the contributions of parents to the next breeding generation.
  - Numerical broodstock collection objectives will be applied to help retain genetic diversity. Minimum broodstock collection objectives are set to allow for spawning of the number of adults needed to minimize loss of some alleles and fixation of others. Maximum collection levels are set for population greater than 200 spawners to allow for at least 50% of escaping fish to spawn naturally each year. For small populations, no maximum is set as an emergency measure;
  - Hatchery incubation and rearing measures will mimic the natural environment to the extent feasible. Hatchery rearing will be limited to a maximum of 75 days post swim-up to minimize the level of intervention into the natural chum life cycle, reducing domestication selection effects; and,
  - all summer chum produced in hatchery programs will be marked to allow for monitoring and evaluation of adult returns.

Allowable Fish Release Levels

The scale of juvenile chum release levels set for each project were guided by the above broodstock collection principles and the condition of the natural summer chum population. Target annual release levels for each watershed based on achieving historical adult run sizes were set as upper limits for each project. The number of fry needed to produce the number of returning adults that will equate to the 1974-78 average run size for the watershed were set as targets. For small populations (<700 escapement), the number of fry needed to assure a minimum population equaling or exceeding 700 was determined. The projects are operated to produce fish at consistent levels, at or near goals between years, leaving no "holes" in production for the terms of the programs. This strategy helps ensure the effectiveness of the programs in quickly boosting abundances, and may assist in maintaining the genetic character of the population between brood years. Monitoring and evaluation results for each project will be used to adaptively manage production strategies, potentially leading to changes in annual production levels.

Disposition of Excess Individuals

Annual adult broodstock collection and juvenile fish release levels associated with each supplementation or reintroduction program are targeted within +/- 10% of levels derived through application of adult collection and fry release criteria in the SCSCI. In the event that circumstances such as unanticipated high adult returns or high egg to fry survival rates lead to possession of fish in excess of program objectives determined by genetic and ecological assessments, supplementation program operators will adhere to set procedures. Adult fish collected at weirs, or captured through other broodstock collection procedures, in excess of 10% of daily, weekly, or total program goals will be returned to the natural environmental at the point of capture. The sex ratio of fish returned must be equivalent to the ratio observed at the time of escapement, collection, or capture. In the event that the total number of eyed eggs or juvenile fish are projected to result in a release in excess of the fish release goal (>100% of the target production number), surplus eggs or fish shall be removed from the population in a random manner and destroyed.

Maintenance of Ecological and Genetic Characteristics of the Natural Population

Standards applied under the SCSCI to propagate fish were designed to ensure that rearing units and procedures are as non-invasive into the natural life cycle of the fish as possible. Following are *general principles* that will be applied to meet objectives calling for maintenance of natural population characteristics for fish taken into the hatchery environment (generally from Kapuscinski and Miller 1993). Expanding upon these principles, specific details regarding actions that will be applied to meet genetic and ecological hazard reduction and population rebuilding strategies are presented in Appendix Report 3.1 of the SCSCI.

- **Broodstock collection and spawning procedures:** Collect and spawn broodstock that are fully representative of the genetic and ecological characteristics of the target population (supplementation) or that show the greatest possible similarity in genetic lineage, life history patterns, and ecology of the originating environment (reintroductions). Numbers to collect and procedures for spawning will be consistent with previously described risk aversion measures implemented to minimize potentially deleterious genetic effects to the target population. Examples include: collection of an appropriate number of fish in a manner that minimizes creating genetic differences between the hatchery and wild spawning portions of the population and potential future genetic alterations of the overall population; use of fish collection methods that will help ensure that broodstock are collected in an unbiased manner; and limitation of the number of fish removed for use as broodstock from a drainage to ensure that the number remaining to spawn in the natural environment will meet minimum population size estimates.

- **Incubation procedures:** Incubate eggs and alevins under density, substrate, light, temperature, and oxygen conditions that simulate, or improve upon natural intergravel survival. For example, green eggs, eyed eggs, and alevins will be maintained at densities and flow levels that produce the highest survivals and quality to the fry stage. Artificial substrate will be provided in all incubation trays or containers, and embryos will be incubated under dark or low-light conditions. Temperature levels and regimes (daily and monthly, seasonally), and oxygen concentrations, will be maintained to mimic conditions in the natural rearing environment as closely as possible. Fry will immediately be transferred to rearing areas upon volitional swim-up or yolk absorption.

- **Juvenile rearing procedures**: Although freshwater rearing upon swim-up has not been shown to be a natural characteristic for summer chum in the region, rearing environments and procedures applied should attempt to simulate attributes of natural conditions that may promote the development of fitness-related behaviors. Attributes addressed in this regard should include rearing water quality, hydraulic characteristics of rearing areas, feeding conditions, feeding behavior, and health and nutritional status at release. Desirable production strategies for maintaining similarity to the wild population may include rearing all fish of a population under the same conditions and mixing families randomly so that unintentional differences in rearing conditions will affect all families equally. General guidelines directed at meeting these objectives include: rearing fish at densities that will lead to the production of high quality, healthy fed fry; rearing fish under semi-natural habitat and feeding conditions to the extent feasible, especially with regard to flow velocities (exercise) and feed application and distribution practices; rearing fish in a sufficient depth of water to enable chum fry to sound when startled, allowing for the retention of standard predator avoidance behavior exhibited by the fish during migration/rearing in the estuary; introducing feed frequently, and during daylight hours only, to mimic the natural environment (constant food availability) and chum fry behavior within it (continuous feeding during migration, predominantly during daylight hours); minimizing direct human contact with fish during feeding and pond maintenance in order to minimize adverse effects on the population regarding association of humans with food and increased vulnerability to predation; maintenance of temperature levels and regimes (daily and monthly, seasonally), and oxygen concentrations, to mimic conditions in the natural rearing environment as closely as possible; and monitoring fish health during rearing, and apply approved therapeutics if necessary to suppress pathogens.

- **Smolt release procedures**: Release procedures will mimic natural migrational characteristics for the life stage at release, including release location, nocturnal timing, and seasonal timing. General fish release guidelines include: assessment of fish health status of all groups prior to release to ensure that their quality, and likelihood for survival, is high; release of fish as fed fry at a size that promotes the highest smolt to adult survival rates, that reduces ecological interactions with co-occurring wild summer chum, and that fosters rapid seaward migration. The targeted release size should be achieved quickly (although in deference to natural out-migration timing parameters) to decrease the likelihood for deleterious genetic effects that may be incurred by extended hatchery residence; matching fish release dates with the time period when naturally-produced fish are known to be present as migrants in the estuary; from data provided by existing WDFW, tribal, or private industry monitoring programs, assess estuarine productivity conditions to match releases with the onset of spring-time plankton blooms in the estuary occurring during the summer chum migration period; release hatchery fish as close to the estuary as is feasible to mimic lower river migrational distances experienced by natural fish (but balanced by the desire to spread spawners homing to the stream of release across all available habitat). Releases should be timed to occur after dusk, but before mid-night to mimic the natural stream emigration period exhibited by natural chum fry. For fish reintroduced into stream where the indigenous population has been extinguished, rear and acclimate the fish at the recipient location prior to liberation to enhance homing. Finally, fry production groups should be mass-released, leading to the arrival of large, instantaneous volumes of fish in the estuary, "swamping" freshwater and nearshore predator standing populations. This latter release measure also promotes schooling of fish in the estuary for migration, adhering to a "safety in numbers" prey fish survival strategy.

Monitoring and Evaluation Standards and Implementing Methods

Monitoring and evaluating the effects of supplementation on the natural summer chum population, and the performance of the overall program in recovering summer chum, are critical objectives of the SCSCI. The basic approach for monitoring and evaluation is to collect information that will help determine 1) the degree of success of each project; 2) if a project is unsuccessful, why it was unsuccessful, 3) what measures can be implemented to adjust a program that is not meeting objectives set forth for the project (Cuenco *et al.* 1993); and, 4) when to stop a supplementation project.

Implementation of the monitoring and evaluation program involved responding to concerns regarding the uncertainty of summer chum supplementation and reintroduction effects. To respond to this uncertainty, the basic approach for monitoring and evaluation activities was refined to specifically address the following four elements (generally from Hard *et al.* 1992):

- The estimated contribution of supplementation/reintroduction program-origin chum to the

  natural population during the recovery process;
- Changes in the genetic, phenotypic, or ecological characteristics of populations (target

and non-target) affected by the supplementation/reintroduction program;

- The need and methods for improvement of supplementation/reintroduction activities in order to meet program objectives, or the need to discontinue a program because of failure to meet objectives; and
- Determination of when supplementation has succeeded and is no longer necessary for recovery.

The following framework was defined as the basis for development and application of a monitoring and evaluation program to address the above four elements:

- Restate supplementation/reintroduction goal in context of application. For example, survival monitoring is initially to provide a basis for assessing success of hatchery returns and ultimately for assessing success of natural origin returns.
- Identify performance measures.
- Develop experimental and sampling design.
- Uniquely mark all hatchery production.
- Collect and analyze data.
- Interpret results.
- Adjust/correct ineffective or inefficient parts of plan.
- Determine how (by what mechanism) revisions will be applied.

The basis for the monitoring and evaluation program set forth in the SCSCI is to address the four elements described above. Monitoring and evaluation responses for some of these elements will provide programmatic information regarding the effectiveness of supplementation within the region. In consideration of implementability and funding concerns, certain monitoring and evaluation activities providing program-wide benefit were required only for selected programs. Other elements provide program-specific information, and were required for each supplementation and reintroduction effort. Methods applied to address each element were specifically defined, applicable to either selected programs or all programs.

Selected Programs

a) Element 1: Estimate the contribution of supplementation/reintroduction program-origin chum to the natural population during the recovery process.

1. Differentially mark all hatchery-origin summer chum fry to allow for distinction from natural-origin fish upon return as adults in fisheries, at hatchery racks, and on the spawning grounds. This should be accomplished by fin-clipping, otolith (thermal) marking, or another permanent, effective method.
2. Conduct spawning ground surveys throughout the summer chum return to enumerate spawners, and to collect information regarding fish origin (via ad-clip fish observation or random sampling of fish heads for otoliths), and age class composition through scale sampling.
3. Estimate the number of naturally spawning hatchery-origin summer chum contributing to each supplemented population’s annual escapement.
4. Monitor escapements of non-supplemented populations to determine the level of straying of supplementation program-origin fish to other drainages.

5. Conduct focused studies to help identify productivity levels (swim-up fry per adult spawner) that can be expected for hatchery-origin fish spawning in the wild. Compare these estimates with fry per spawner levels reported for wild summer chum salmon spawners in the region, or in other regions.

a. Enumerate natural escapement of F1 generation reintroduced fish.

b. Use F1 chum collected as broodstock to obtain age structure, fecundity, and sex ratio data. Then determine egg retention of spawned out fish that have been allowed to spawn naturally. From this information, estimate natural deposition of eggs in stream.

c. Enumerate progeny (out-migrating fry) of F1 adults to estimate egg to fry survival and to establish the baseline number of fry contributing to subsequent brood year returns.

d. Capture, sample and pass upstream resultant F2 generation spawners (three, four, and five years later) to assess survival and reproductive success of naturally-spawning hatchery-origin fish.

6. Estimate the total recruitment (fisheries contribution and escapement) of supplementation program origin chum. Compare hatchery fish fry to adult survival rates with estimates for wild fish to measure the effectiveness of each program

b) Element 2: Monitor and evaluate any changes in the genetic, phenotypic, or ecological characteristics of the populations presently affected by the supplementation program. Variably affected programs and populations.

1. Collect additional GSI data (allozyme or DNA-based) from regional summer chum adult populations to determine the degree to which discrete populations exist in the individual watersheds.
2. Continue GSI allozyme collections of summer chum spawners throughout the region for comparison with past collections to monitor changes in allelic characteristics, and with the intent to assess whether the supplementation program has negatively affected the genetic diversity of natural populations (after Phelps *et al.* 1994).
3. To assess the effect of past or on-going supplementation activities on the heterozygosity of target populations, collect tissue samples from representative juveniles for GSI analysis, allowing for a comparison of the genetic diversity of progeny samples to the existing baseline population profile.
4. Continue collecting and archiving DNA samples for future analysis.
5. Monitor natural spawner abundance and distribution of wild and hatchery-origin fish. Determine spawner densities and identify locations of preferred areas. Define annual and longterm changes in spawning distribution of the populations.
6. Determine if spawning ground distribution, timing, and use by hatchery-origin fish is consistent with traits exhibited by wild-origin spawners.
7. If possible, monitor fry emigration behavior upon release to assess whether natural migratory patterns (timing, migration rates, areas used) change.

All Programs

c) Element 3: Determine the need, and methods, for improvement of supplementation or

reintroduction operations or, if warranted, the need to discontinue the program.

1. Mark all hatchery summer chum juveniles produced through the supplementation or reintroduction programs to allow for assessments of contribution and natural-origin recruitment rates.

2. Determine the pre-spawning and green egg to released fry survivals for each program at various life stages.

   a) Monitor growth and feed conversion for summer chum fry.

   b) Determine green egg to eyed egg, eyed egg to swim-up fry, and swim-up fry to released fry survival rates for summer chum.

   c) Maintain and compile records of cultural techniques used for each life stage, such as: collection and handling procedures, and trap holding durations, for chum broodstock; fish and egg condition at time of spawning; fertilization procedures, incubation methods/densities, temperature unit records by developmental stage, shocking methods, and fungus treatment methods for eggs; ponding methods, start feeding methods, rearing/pond loading densities, feeding schedules and rates for juveniles; and release methods for one gram fry.

   d) Summarize results of tasks for presentation in annual reports.

   e) Identify where the supplementation program is falling short of objectives, and make recommendations for improved fry production as needed.

3. Determine if broodstock procurement methods are collecting the required number of adults that represent the demographics of the donor population with minimal injuries and stress to the fish.

   a) Monitor operation of adult trapping operations, ensuring compliance with established broodstock collection protocols for each station.

   b) Monitor timing, duration, composition, and magnitude of each run at each adult collection site.

   c) Maintain daily records of trap operation and maintenance (e.g., time of collection), number and condition of fish trapped, and environmental conditions (e.g., river stage, tide, water temperature).

   d) Collect biological information on collection-related mortalities. Determine causes of mortality, and use carcasses for stock profile sampling, if possible.

   e) Summarize results for presentation in annual reports. Provide recommendations on means to improve broodstock collection, and refine protocols if needed for application in subsequent seasons.

4. Monitor fish health, specifically as related to cultural practices that can be adapted to prevent fish health problems. Professional fish health specialists supplied by WDFW (or USFWS for federal agency operations) will monitor fish health.

   a) Fish health monitoring will be conducted by a fish health specialist. Significant fish mortality to unknown causes will be sampled for histopathological study.

   b) The incidence of viral pathogens in summer chum broodstock will be determined by sampling fish at spawning in accordance with procedures set forth in the Salmonid Disease Control Policy of the Fisheries Co-Managers of Washington State (NWIFC and WDFW 1998).

c) Recommendations on fish cultural practices will be provided on a monthly basis, based upon the fish health condition of chum fry.
d) Fish health monitoring results will be summarized in an annual report.

d) Element 4: Collect and evaluate information on adult returns.

This element will be addressed through consideration of the results of previous "Elements 1, 2, and 3," and through the collection of information required under adaptive criteria that will be used as the basis for determining when to stop a supplementation or reintroduction program.

1. Collect age, sex, length, average egg size, and fecundity data from a representative sample of broodstock used in each supplementation program for use as baseline data to document any phenotypic changes in the populations.
2. Commencing with the first year of returns of progeny from naturally-spawned, hatchery-origin summer chum, evaluate results of spawning ground surveys and age class data collections to:
    a) Estimate the abundance and trends in abundance of spawners;
    b) Estimate the proportion of the escapement comprised by chum of hatchery lineage, and of wild lineage;
    c) Through mark sampling, estimate brood year contribution for hatchery lineage and wild-origin fish.
3. Using the above information, determine whether the population has declined, remained stable, or has been recovered to sustainable levels. The ability to estimate hatchery and wild proportions will be determined by implementation plans, budgets, and assessment priorities.
4. Compare newly acquired electrophoretic analysis data reporting allele frequency variation of returning hatchery and wild fish with baseline genetic data. Determine if there is evidence of a loss in genetic variation (not expected from random drift) that may have resulted from the supplementation program.
5. Collect GSI and run timing information in summer chum streams where Finch Creek-lineage fall chum have been introduced to evaluate the risks of genetic introgression and spawning ground interaction between the two races.

Annual Monitoring and Evaluation Report

Annual reports describing monitoring and evaluation actions, findings and recommendations will be assembled for each supplementation or reintroduction program. The reports will summarize data collected through monitoring and evaluation activities, provide an analysis of the data and an interpretation of results, and suggest mechanisms for applying revisions necessary to adjust ineffective or inefficient portions of the programs. The annual report will be consistent in content, structure, and detail with annual reports currently required by NOAA Fisheries for hatchery projects authorized under the ESA. Each year, annual monitoring and evaluation reports will be reviewed and evaluated by the co-managers, USFWS, and NOAA Fisheries to assess the effectiveness and effects of the supplementation and reintroduction programs. Adjustments that are needed, if any, will be discussed and implemented as determined to be necessary to meet the objectives of the SCSCI.

References

Ames J. and K. Adicks. 2003. Chum salmon supplementation: Bane or Boon? Proc. of the Twenty-first Northeast Pacific Pink and Chum Salmon Workshop. Depart. Fisheries and Oceans. Vancouver, B.C. Canada.

Busack, C.A. and K.P. Currens. 1995. Genetic Risks and Hazards in Hatchery Operations: Fundamental Concepts and Issues. American Fisheries Society Symposium 15:71-80.

Cuenco, M.L., T.W.H. Backman, and P.R. Mundy. 1993. The used of supplementation to aid in natural stock restoration. *In*, Genetic Conservation of Salmonid Fishes, J.G., Cloud and G.H. Thorgaard, eds. Plenum Press, New York.

Hard, J.J., R.P. Jones, M.R. Delarm, and R.S. Waples. 1992. Pacific salmon and artificial propagation under the Endangered Species Act. NOAA Tech. Memo. NMFS F/NWC-2, 56 p.

Johnson, T.H. and C. Weller. 2003. On-going supplementation programs for summer chum salmon in the Hood Canal and Strait of Juan de Fuca regions of Washington state. Proc. of the Twenty-first Northeast Pacific Pink and Chum Salmon Workshop.. Depart. Fisheries and Oceans. Vancouver, B.C. Canada.

Kapuscinski, A. R., and L.M. Miller. 1993. Genetic hatchery guidelines for the Yakima/Klickitat Fisheries Project. Co-Aqua, 2369 Bourne Avenue, St. Paul, MN.

Northwest Indian Fisheries Commission (NWIFC) and Washington Department of Fish and Wildlife. 1998. Salmonid disease control policy of the fisheries Co-managers of Washington state. Formally adopted on March 17, 1998. Fish Health Division, Hatcheries Program. Washington Dept. Fish and Wildlife, Olympia.

Pacific Northwest Fish Health Protection Committee (PNFHPC). 1989. Model comprehensive fish health protection program. 19 p.

Phelps, S.R., B.M. Baker, P.L. Hulett, and S.A. Leider. 1994. Genetic analyses of Washington steelhead: initial electrophoretic analysis of wild and hatchery steelhead and rainbow trout. Fisheries Management Program Report 94-9, Washington Department of Fish and Wildlife. Olympia, WA.

Washington Department of Fish and Wildlife (WDFW) and Point No Point Treaty Tribes (PNPTT). 2000. Summer chum salmon conservation initiative - Hood Canal and Strait of Juan de Fuca region. Washington Department of Fish and Wildlife. Olympia, WA.

Tynan, T. J. 1997. Life history characterization of summer chum salmon populations in the Hood Canal and eastern Strait of Juan de Fuca regions. Tech. Report # H97-06. Hatcheries Program, Wash. Dept. Fish and Wildlife, Olympia. 99 p.

Waples, R.S. 1996. Toward a risk/benefit analysis for salmon supplementation. Unpublished paper presented at a workshop on captive breeding in the restoration of endangered species. October 1996 in Newport, OR.