Stock Management Plan for Nisqually Fall Chinook Recovery

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Final

Prepared by the Nisqually Chinook Work Group

Nisqually Chinook Work Group

The Nisqually Chinook Stock Management Plan is a collaborative product between Nisqually Indian Tribe and Washington Department of Fish and Wildlife with assistance from consultants at ICF. The individuals listed below attended one or more of the Nisqually workshops or contributed to developing the management plan.

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Acronyms and Abbreviations

°C	degrees Celsius
APR	Annual Project Review
CDDFL	Centralia Diversion Dam Fish Ladder
CV	coefficient of variation
EDT	Ecosystem Diagnosis and Treatment
ESA	Endangered Species Act
ESU	evolutionarily significant unit
GMR	genetic mark-recapture
HSRG	Hatchery Scientific Review Group
MP-PNI	Multi-Population PNI
Nb	number of breeders
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
pHOS	percent hatchery-origin in natural spawning
PNI	proportionate natural influence
RM	river mile
tGMR	trans-generational genetic mark recapture
Tribe	Nisqually Indian Tribe
VSP	viable salmonid populations
WDFW	Washington Department of Fish and Wildlife

Chapter 1
Introduction

Salmon are important to the economic, social, cultural, and aesthetic values of the people in the Pacific Northwest, including the Nisqually Indian Tribe (Tribe). To ensure sustainable salmon runs and fishing in perpetuity, the Tribe and the Washington Department of Fish and Wildlife (WDFW) co-managers, and several watershed partners have led a multidecade-long effort to protect and restore the watershed, resulting in some of the best Chinook habitat quality and quantity in Puget Sound.

Recovery of Chinook is important to the Tribe and is guided by the following overarching goal (Nisqually Chinook Recovery Team 2001).

> …to provide meaningful harvest for treaty and non-treaty fisheries in the Nisqually River and to restore a viable, self-sustaining, and locally-adapted population of fall Chinook salmon that adds to the spatial diversity, abundance, and recovery of the Puget Sound Chinook ESU.

The central importance of Chinook salmon to the Tribe's community and treaty fishery is reflected in its treaty harvest goal of 10,000 to 15,000 Nisqually fall Chinook annually in the in-river fishery.

Native Nisqually River fall and spring Chinook were extirpated[1] over half a century ago as a result of habitat degradation, hydropower development, and other anthropogenic activities including high harvest rates[2] associated with hatchery operations and hatchery straying. The Nisqually River watershed, like most of southern Puget Sound, has a long history of hatchery enhancement.[3] From 1956 to 1988, fall Chinook of Green River origin were regularly introduced to the Nisqually River. Hatchery production is currently necessary for sustaining harvest that natural production cannot support due to habitat degradation and reduced population productivity. Figure 1-1 shows the location of the Nisqually watershed in the context of the broader Puget Sound region.

The Tribe initiated hatchery production in 1979 at Kalama Creek Hatchery and 1990 at Clear Creek Hatchery with the sole purpose of supporting harvest. Initial releases occurred the first year following the start of production at the respective facilities. The Tribe began managing the Kalama Creek and Clear Creek hatchery program in 1994 with a 600,000 Chinook release goal at Kalama Creek and with a 3.4 million Chinook release goal at Clear Creek. The Kalama Creek hatchery operations are funded by the Bureau of Indian Affairs; Clear Creek Hatchery operations are funded by Tacoma City Light as mitigation for the effects of Nisqually River hydropower project per a 1989 settlement agreement. Figure 1-2 shows the locations of these hatcheries in the Nisqually watershed. The last introductions of Chinook salmon (of Green River origin) to the Nisqually River were in 1988. Since then, the tribal hatchery programs in the system have been self-sufficient (Nisqually Chinook Recovery Team 2001).

Figure 1-1. Nisqually Watershed

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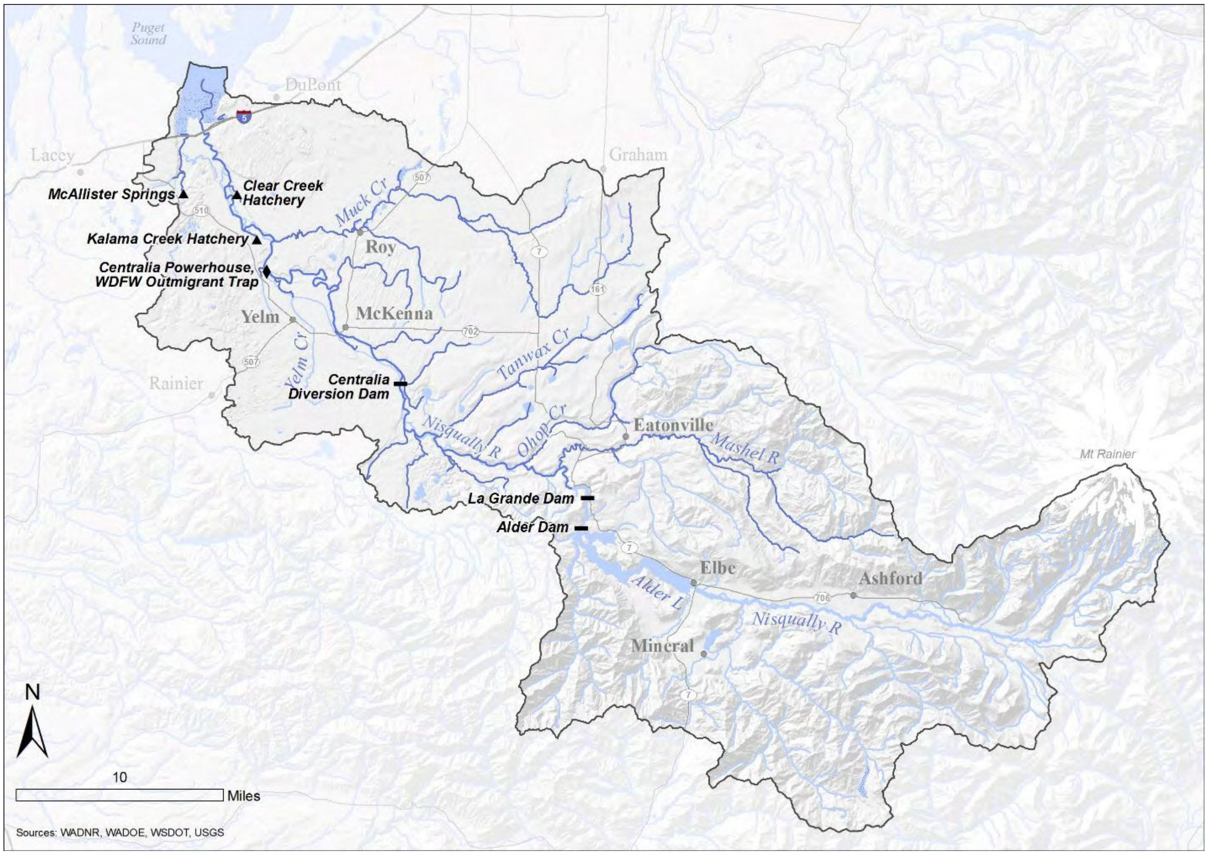
[1] Locally extinct in the Nisqually Basin.

[2] As in most of southern Puget Sound, harvest rates for fall Chinook have been based on full harvest of hatchery-produced fish.

[3] Records indicate that hatchery fall Chinook have been planted in the Nisqually River since 1943, and likely earlier. Data from early years on stock origin are not available, but plants in the 1960s and 1970s were from at least nine different Puget Sound and Hood Canal hatcheries.

Figure 1-2. Hatchery, Hydropower, and Fishery Facilities in the Nisqually Watershed



The Nisqually River fall Chinook population has been managed as a composite stock (hatchery-bred and naturally spawned).[4] Harvest has been managed to achieve hatchery broodstock escapement[5] and natural spawning escapement with minor consideration of composition of hatchery- and natural-origin adults in the escapement.[6] Since 2004, an annual average of approximately 2,000 fall Chinook (hatchery- and natural-origin) spawned naturally in the Nisqually River[7] and 1,400 natural-origin adults returned to the system.

This Stock Management Plan for Nisqually Fall Chinook Recovery replaces the 2011 stock management plan (Nisqually Chinook Work Group 2011) as the guidelines for adaptively managing the Nisqually fall Chinook stock (hatchery, harvest, escapement) to promote adaptation of the stock to the river's unique conditions (i.e., temperature, flow, food and seasonality), increase spawning abundance of natural-origin Chinook, and ultimately achieve a self-sustaining, productive population.

Stock management is one element of a broader integrated management program that is required for recovery of Nisqually fall Chinook salmon. An integrated management program considers all

[4] The Nisqually Tribe stopped importing fish from the Green River in 1996 to promote adaptation of the hatchery stock to the river's unique conditions. WDFW continued to import broodstock for its McAllister Creek hatchery until the hatchery closed in 2002.

[5] A sufficient number of fish avoid harvest and continue upstream to the hatchery to be used in the hatchery breeding program.

[6] Hatchery- and natural-origin Chinook avoid harvest and continue upstream to the natural spawning grounds,

[7] Natural spawning occurs in 42 miles of the mainstem Nisqually River accessible to anadromous salmonids as well as tributaries, the Mashel River, and other smaller tributaries.

factors affecting Nisqually fall Chinook salmon throughout their life cycle, including freshwater, estuarine, and marine habitats; ecological interactions; harvest; and the hatchery program (Rawson and Crewson 2017; Hatchery Scientific Review Group 2014).

In 1999, Puget Sound Chinook salmon was listed as threatened under the Endangered Species Act (ESA). The *Nisqually Chinook Recovery Plan* (Nisqually Chinook Recovery Team 2001), the product of a 3-year effort to develop a habitat protection and restoration plan for the Nisqually watershed and the initial step in an integrated multispecies plan for the watershed, was released in 2001. The plan was used to chart the path to Nisqually Chinook recovery and contribute more broadly to Puget Sound Chinook recovery. The plan has provided the overarching recovery framework for Nisqually Chinook over the last 15 years and guided a strategic ecosystem-scale habitat protection and restoration effort. In 2007, the National Oceanic and Atmospheric Administration (NOAA) approved the Puget Sound Recovery Plan, which incorporated the 2001 *Nisqually Chinook Recovery* Plan and other watershed plans for the Puget Sound Chinook evolutionarily significant unit (ESU).

Puget Sound steelhead was listed as threatened under ESA in 2007. The *Draft Nisqually Steelhead Recovery Plan* was released in 2010 to identify and prioritize factors affecting Nisqually River steelhead and fold steelhead recovery into the multispecies plan for the watershed.

In 2010, the Puget Sound Indian Tribes and WDFW released the *Draft Puget Sound Chinook Resource Management Plan*, which represents the legal plan for permitting take of listed species under ESA resulting from fisheries in the state (Puget Sound Indian Tribes and Washington Department of Fish and Wildlife 2010).

The National Marine Fisheries Service (NMFS) Supplement to the Puget Sound Salmon Recovery Plan (National Marine Fisheries Service 2006; Ruckleshaus et al. 2002) identified the Nisqually Chinook salmon population or another late-timed population in Central/South Puget Sound as needing to be at low risk for the Puget Sound Chinook salmon ESU to be considered viable. At the time, NMFS concluded the Nisqually population to be among those that would have the best chance of recovery because of habitat conditions. In 2010, the NMFS Northwest Region Puget Sound Domain Team (2010) proposed an approach to recover Puget Sound Chinook. The approach identified the Nisqually Chinook population as a Tier 1 population, which is most important for preservation, restoration, and recovery of the ESU, and has greater importance to overall ESU viability relative to other ESU populations.[8] Nisqually Chinook are proposed as Tier 1 based on the existence of functional habitat relative to other fall-run Chinook watersheds in the Central/South Puget Sound biogeographical region, and the watershed's future potential to support a self-sustaining and productive Nisqually Chinook population.

In 2009, the Tribe started developing a Hatchery and Genetic Management Plan[9] (HGMP) to support a permit from NOAA Fisheries for take under ESA related to Nisqually Chinook hatchery operations. The Nisqually Chinook Work Group (2011) released the *Nisqually Chinook Stock Management Plan* to support the HGMP, as well as the *Harvest Management Component of the Comprehensive Management Plan* for Puget Sound Chinook (Puget Sound Indian Tribes

[8] Nisqually Chinook is identified as a Tier 1 population (must achieve recovery) within the Central/South Puget Sound Major Population Group. This Major Population Group also includes the Cedar, Sammamish, White, Green, White, and Puyallup River Chinook.

[9] A Hatchery Genetic Management Plan (HGMP) describes, in a format prescribed by NOAA Fisheries, the operation of the artificial production program for salmon and steelhead in the Puget Sound region and the potential effects of each program on listed species.

and Washington Department of Fish and Wildlife 2010). As described in detail in Chapter 2, *Recovery Successes, Challenges, and Adaptive Response*, the 2011 plan objectives were not met. This 2017 stock management plan replaces the 2011 plan and supports the 2017 Nisqually Chinook HGMP.

Chapter 2
Recovery Successes, Challenges, and Adaptive Response

This chapter describes the elements of recovery planning, implementation, and evaluation that have occurred since the 2001 plan. It documents completed and planned restoration and protection projects, the development of the 2011 stock management plan to take advantage of the resulting improved habitat conditions, and the adaptive response to the evaluation of the first 5 years of the plan's implementation.

Developments in the Nisqually River since the 2001 Plan

Since the implementation of the *Nisqually Chinook Recovery Plan* (Nisqually Chinook Recovery Team 2001), major habitat restoration initiatives have been accomplished and efforts to protect existing habitat, monitor and evaluate restoration activities, and develop and implement a stock management plan to take advantage of habitat improvements have occurred.

Habitat Restoration and Protection

Many, but not all, of the major habitat elements of the 2001 plan have been implemented (Table 2-1) and further protection and restoration actions are planned for implementation. Modeled assessments of habitat potential and data collected during restoration monitoring suggest that fall Chinook potential has increased substantially since the habitat components of the recovery plan were started in 2001 (e.g., monitoring studies in the Nisqually delta confirms broad use of restored habitat and increased capacity) and will continue to increase as projects mature (e.g., riparian revegetation, natural recruitment of woody material to streams, and establishment of estuarine channel network) and additional projects are implemented (Figure 2-9). Table 2-1 lists the recovery projects implemented since 2001, and identifies the major recovery initiatives they fit within. Figure 2-1 depicts the major completed, ongoing, and conceptual habitat restoration and protection initiatives.

Table 2-1. Habitat Restoration and Protection Projects Implemented since 2001

Year	Recovery Initiative	Project
1991	Mainstem Nisqually Restoration and Protection	Large sections of the Nisqually mainstem are protected by Fort Lewis and Nisqually Indian Reservation. However, sections of the mainstem and tributaries are not protected. The Nisqually estuary is severely reduced in area from dikes on both sides of river.
1996	Nisqually Delta Restoration	Red salmon slough estuary restoration: dike breached to restore 12 acres of salt marsh.
1997		Minimum flows established for hydropower impacted mainstem reaches (LaGrande bypass reach, the mainstem to the Centralia City Light Yelm Hydroproject diversion dam (Centralia Diversion Dam), and the Yelm project diversion reach downstream of the dam) during relicensing of the Nisqually River project.
2001	Mainstem Nisqually Restoration and Protection	63% of mainstem Nisqually River shoreline in protected status.

Year	Recovery Initiative	Project
2004	Mashel River Restoration and Protection	Lower Mashel Restoration Project (install 7 logjams).
2005	Mainstem Nisqually Restoration and Protection	70% of mainstem Nisqually River shoreline in protected status.
2006	Nisqually Delta Restoration	Red Salmon Slough dike removal for estuary restoration (150 acres + wetland and surge plain).
2007	Mashel River Restoration and Protection	Eatonville Mashel Phase 1 project (12 logjams).
2009	Nisqually Delta Restoration	NNWR estuary restoration with dike removal restoring 760 acres.
2010	Mashel River Restoration and Protection	Eatonville Mashel Phase 2 project (installed 23 logjams) .
	Ohop Restoration	Ohop Phase 1 completed, restored 1 mile of creek and protected 100 acres of floodplain.
2011	Mainstem Nisqually Restoration and Protection	75% of Nisqually River mainstem shoreline in protected status.
2013		Produce new habitat action plan; incorporate updated steelhead EDT modeling.
2015	Ohop Restoration	Ohop Phase 3 complete; 121 acres permanently protected and 1.4 miles of creek restored.
	Nisqually Community Forest Initiative	Nisqually Community Forest becomes 501(c)(3) organization with a goal to purchase over 100,000 acres of private timberlands in the upper watershed to manage for ecosystem services and local economies.
2016	Mashel River Restoration and Protection	First 640 acres of upper Mashel watershed purchased for inclusion in Nisqually Community Forest.
2017	Mainstem Nisqually Restoration and Protection	77% of Nisqually River mainstem shoreline in protected status.
	Mashel River Restoration and Protection	Mashel Phase 3 restoration planned.
	Nisqually Community Forest Initiative	1280 acres of upper Mashel watershed purchased for inclusion in Nisqually Community Forest.
	Nisqually Delta Restoration	Estuary research confirms broad use of restored habitat and increased capacity.

Figure 2-1. Major Completed, Ongoing, and Conceptual Habitat Recovery Initiatives

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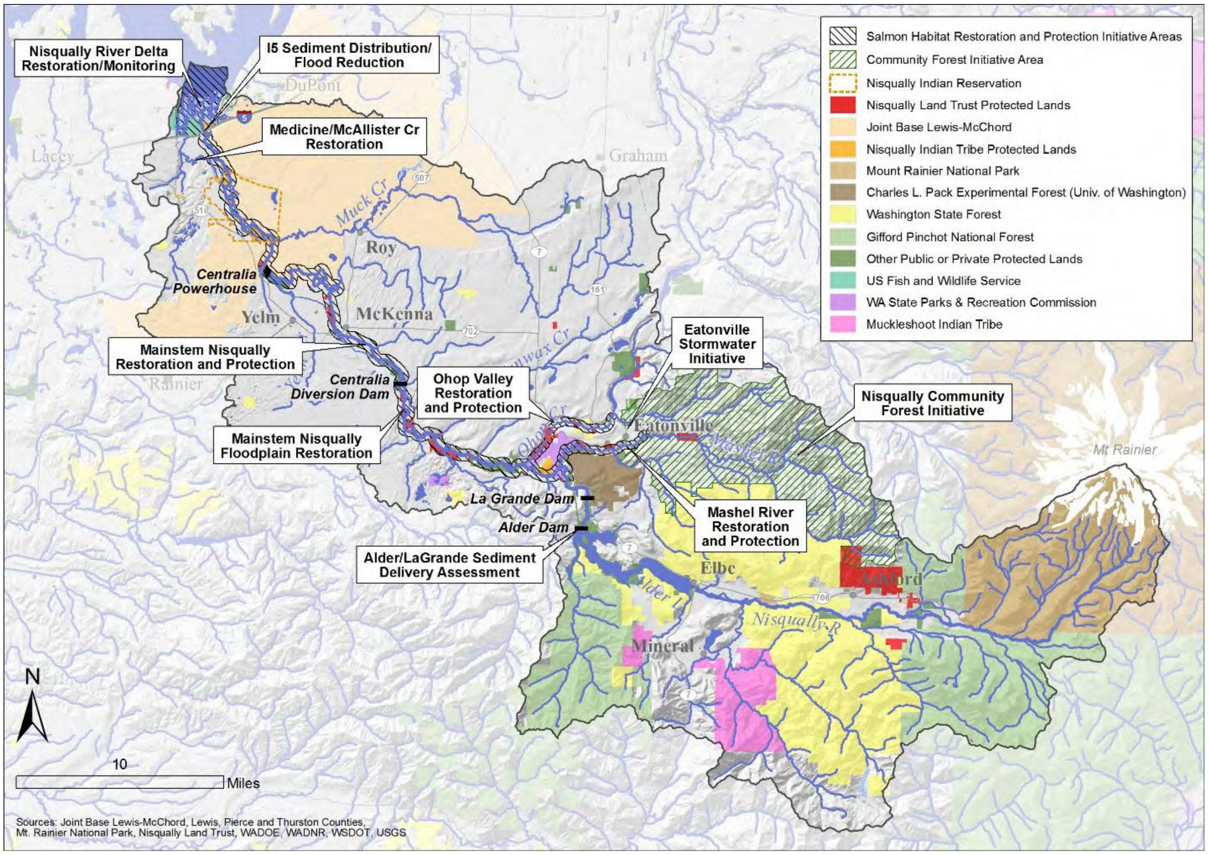

Stock Management

Based on the significant implementation of habitat protection and restoration actions identified in the 2001 recovery plan and estimated large natural-origin adult runs in 2007 and 2008 from naturally spawning Chinook, the co-managers decided to take the next step identified in the 2001 Chinook recovery plan. The next step in the 2001 plan was to foster adaptation of the population to the Nisqually River system by reducing contribution of hatchery fish to natural production a by managing harvest, the hatcheries, and natural spawning escapement.

While habitat potential had improved considerably and was expected to improve further, a substantial portion of this current and future habitat potential was going unrealized. The co-managers concluded that habitat potential was unrealized because of hypothesized low fitness level of the population due to hatchery effects as described by the Hatchery Scientific Review Group (HSRG) (2014).[1]

In 2010, several milestones occurred and additional tools were available to manage the population and monitor productivity and abundance of the population leading to the decision to transition stock management in the river. In 2006, sport fishery regulations in the river were revised to require the release of all adult Chinook with an intact adipose fin (unmarked adults). The hatchery releases achieved a mark rate of 95% with the 2010 release improving the co-

[1] With the native Nisqually fall Chinook population extirpated, the current Green River–based population has undergone multiple generations of hatchery propagation and influence, which has disrupted the natural selection of population characteristics that are tailored to local conditions.

managers ability to manage to reduce harvest of natural-origin Chinook. In 2009, WDFW began operating a juvenile outmigrant trap at river mile (RM) 12.8, and juvenile production in that year and the next indicated an abundant natural population. Finally, in 2010, the Harvest Management Component of the Comprehensive Management Plan for Puget Sound Chinook (Puget Sound Indian Tribes and Washington Department of Fish and Wildlife 2010) was developed to guide annual harvest. The schedule for Nisqually Chinook was to reduce the total exploitation rate from 72% in 2010 to 47% by 2014. The schedule was subsequently revised and the 47% exploitation rate was achieved in 2016.

HSRG (2014) has concluded that hatchery programs should either be managed to achieve proper integration with or be isolated from natural populations—depending on the unique circumstances of the program and the natural population—to ensure that hatchery programs are not an impediment to recovery.[2] The biological principle behind proper integration or segregation of hatchery programs is local adaption. When populations are allowed to adapt to the local conditions of the natural environment, their productivity is expected to increase.

HSRG proposed a third type of program—the "stepping-stone" program—in its review of Columbia River hatchery programs (Hatchery Scientific Review Group 2009); it includes a small integrated program as a broodstock generator to support a larger isolated harvest program.[3] The intent of a stepping-stone program is to support harvest while allowing populations to adapt to the local conditions of the natural environment.

HSRG has developed criteria for hatchery influence on natural populations for integrated and isolated programs based on the population's biological significance (Hatchery Scientific Review Group 2014). For integrated programs the intent is for the combined hatchery/natural population to attain the genetic characteristics of the locally adapted natural population. This requires that the natural habitat has a stronger selective influence than the hatchery environment. To this end, HSRG concluded that the proportion of hatchery broodstock comprising natural-origin fish (pNOB) must be greater than the proportion of the natural spawning population comprising hatchery-origin fish (pHOS). The proportionate natural influence (PNI) is an approximate measure of gene flow and is calculated as pNOB/(pNOB+pHOS). For populations with the highest biological significance within their ESU (Primary or Tier 1), the PNI index should exceed 0.67. For populations with different roles within the ESU, a PNI of 0.5 may be acceptable.

For isolated programs the intent is to maintain a genetically distinct hatchery population, isolated from the natural population. For populations with the highest biological significance within their ESU, HSRG has recommended that pHOS be less than 5%. For other populations, pHOS values up to 10% may be acceptable.

HSRG has modeled the long-term genetic risks to natural populations of hatchery strays using the phenotypic fitness model described by Ford (2002). The analysis of hatchery effects on natural Nisqually Chinook completed in 2011 adopted the fitness model parameters used by

[2] In the isolated approach, the intent is to limit the fraction of natural spawners that are of hatchery-origin and manage the hatchery as a genetically distinct population, promoting adaptation to the hatchery environment. In the integrated approach, the intent is to manage the hatchery and natural components as one population, local adaptation to the natural environment is achieved by managing gene flow such that gene flow from the natural component to the hatchery component is higher.

[3] A stepping-stone (or two-staged) hatchery program combines a small integrated program and larger isolated program when the natural population is too low to support a fully integrated program. It then transitions into a fully integrated program once natural production is sufficient to provide the required number of natural-origin fish in the broodstock.

HSRG in the Pacific Northwest, including a fitness floor of 50% to limit the maximum fitness effects on a population. The high percent of hatchery fish spawning in nature over multiple generations and that hatchery fish in the system were derived from a hatchery stock outside the watershed suggests the maximum effect is appropriate for Nisqually Chinook.

The previously described PNI criteria for integrated programs also applies to stepping-stone programs because the goal of local adaptation is the same. However, the PNI calculation for integrated programs presented by HSRG does not apply to stepping-stone programs. The 2011 plan did not make a distinction between naturally spawning adults from the stepping-stone program and adults from the integrated program in the calculation of PNI. In other words, pHOS in the PNI formula was the combined integrated and stepping-stone hatchery-origin spawners. In 2017, Craig Busack with NOAA Fisheries provided a calculation of PNI applicable to stepping-stone programs to be used for developing decision rules for Chinook local adaptation in the Nisqually. The plan and decision rules will be updated with new data and consistent with the check points described in the Colonization Phase. The hatchery strategy during local adaptation, including the addition of a stepping-stone program, is based on current scientific thinking and data. It is also based on the assumption that the magnitude of natural-origin spawners relative to the hatchery component of natural spawners will be sufficient at the transition from colonization to local adaptation to achieve a PNI greater than 0.50, given the hatchery production and harvest objectives. This strategy will be reviewed at the point of transition to local adaptation to ensure the strategy that is adopted reflects best science and information at that time.

The 2011 stock management plan (Nisqually Chinook Work Group 2011) was developed, based on the findings and principles described above, to improve natural population fitness by minimizing the genetic and ecological influence of hatchery fish on the naturally spawning population. The plan included the following measures.

- **Reduce hatchery-origin spawning.** Install and operate a weir at river kilometer 20.6 on the mainstem Nisqually River to remove hatchery-origin adults to limit the proportion of hatchery-origin Chinook naturally spawning. Proportion of hatchery spawners (pHOS) to be limited to less than 10%.
- **Improve genetic continuity of hatchery program.** Implement an integrated and stepping-stone hatchery program,[4] by operating the Kalama hatchery as an integrated broodstock generator (using hatchery- and natural-origin Chinook in the broodstock) and using broodstock from the Kalama hatchery return (integrated fish returns) in the Clear Creek hatchery.
- **Reduce exploitation rates on natural-origin adults.** Reduce harvest rates for natural-origin adults in the preterminal and terminal fisheries to limit the total exploitation rate to 47% and increase hatchery component of terminal harvest to maintain harvest goal.

[4] The plan will be updated based on new data and information consistent with the check points described in the Colonization Phase. The hatchery strategy during local adaptation, including inclusion of a stepping-stone program, is based on current scientific thinking and data, and the assumption that the magnitude of natural-origin spawners relative to the hatchery component of natural spawners will be sufficient at the transition from colonization to local adaptation to achieve a PNI greater than 0.50 given the hatchery production and harvest objectives. This strategy will be reviewed at the point of transition to local adaptation to ensure the strategy that is adopted reflects best science and information at that time.

These measures were intended to improve population adaptation to local conditions and overall fitness as measured by high PNI on the composite hatchery- and natural-origin population.[5] This hypothesis is revisited in detail in Chapter 3, *Phased Recovery Approach*.

The feasibility of this approach, which was dependent on accurate identification of hatchery-origin adults in harvest and escapement, was based on dramatically improved mark rates of hatchery fish through use of auto-marking trailers; by 2010, mark rates were at over 95% efficiency.

The weir had to achieve an efficiency of 95% and meet the following performance criteria established by a multiagency weir evaluation team.

- Unbiased trapping
- Trapping throughout the run
- Negligible influence on spawner distribution
- Measurable trapping efficiency

The co-managers began implementing the plan, including operation of the weir, in 2011. During its 5 years of operation, the weir faced numerous challenges: during the first year of operation, multiple design issues were discovered; a late-September 2013 flood ended weir operation early for the season; and drought and unusually warm water temperatures in 2015 led to problems with weir operation.

Monitoring for the years 2011 through 2015 concluded that the weir was not a success: it did not achieve a 95% efficiency rate or meet the performance criteria. It was also expensive to operate and required a high level of staff. The co-managers concluded in 2015, based on these factors, that the weir was not a sustainable method for moving the population toward adaptation to local conditions and improved fitness.

Other monitoring activities such as the juvenile outmigrant trap operated by WDFW beginning in 2009 and an adult video counter at the Centralia City Light Yelm Hydroproject diversion dam (Centralia Diversion Dam) installed in 2014 provided additional information about the status of natural production.

In 2015, the combination of poor environmental conditions in the freshwater and marine environments leading to low population abundance, and failed weir operations resulted in the decision that the 2011 plan was unworkable.

To address poor natural spawning in 2015, 785 adults were trucked from the Clear Creek and Kalama Creek hatcheries and released to natural spawning. The co-managers began considering other options for managing the hatcheries and reducing hatchery strays to natural spawning. In 2016, 500,000 juvenile Chinook were transferred from the Clear Creek Hatchery to McAllister Springs for acclimation and release. The objective of this release was to provide a treaty net fishery at the mouth of McAllister Creek with lower impacts on natural-origin adults returning to the Nisqually River and to reduce straying of hatchery-origin returns to natural spawning grounds. In 2017, this release was increased to 1 million and the hatchery on-station release at Clear Creek was reduced from 3.4 million to 2.4 million.

Current status of the natural population is described in the following section with respect to juvenile and adult abundance and productivity.

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[5] PNI is calculated as pNOB/(pNOB + pHOS). It can be thought of as the percentage of time the genes of a composite population spend in the natural environment.

Current Status of Natural Population

In determining the status of the Nisqually fall Chinook population, several parameters are considered: productivity, abundance, spatial diversity, and life-history diversity. Collectively, these parameters describe attributes of viable salmonid populations (VSP). The following indicators of population performance were considered for each of the VSP attributes.

- **Productivity**: freshwater productivity (measured number of outmigrants[6] per spawner), delta and marine survival (measured in number of adult recruits per outmigrant[7]) and life cycle productivity (measured in number of adult recruits per natural spawner).
- **Abundance**: number of juvenile outmigrants, number of natural-origin adult recruits, number of natural-origin annual run to the river, and number of natural-origin escaping fisheries to spawn in the wild.
- **Spatial diversity**: distribution of natural-origin spawners and juveniles relative to spawning and rearing habitat in freshwater and the Nisqually delta.
- **Life-history diversity**: adult migration and spawn timing, age at spawning, adult body size at age, age and life stage at outmigration, body size and timing of outmigration, and juvenile habitat rearing choice.

Figures 2-2 and 2-3 depict Nisqually fall Chinook abundance as indicated by annual unmarked, natural-origin adult run to the river[8] (Figure 2-2) and natural spawning escapement by natural- and hatchery-origin (Figure 2-3). Figures 2-4 and 2-5 depict harvest impacts affecting annual run to the river and escapements as indicated by terminal (in-river) harvest rates (Figure 2-4) and total exploitation rates (Figure 2-5) on unmarked, natural-origin Chinook.[9]

As shown in Figure 2-2, the average number of natural-origin adult returns (adults returning to the Nisqually River) has been less than 1,000 Chinook in recent years, following two strong returns in 2007 and 2008.

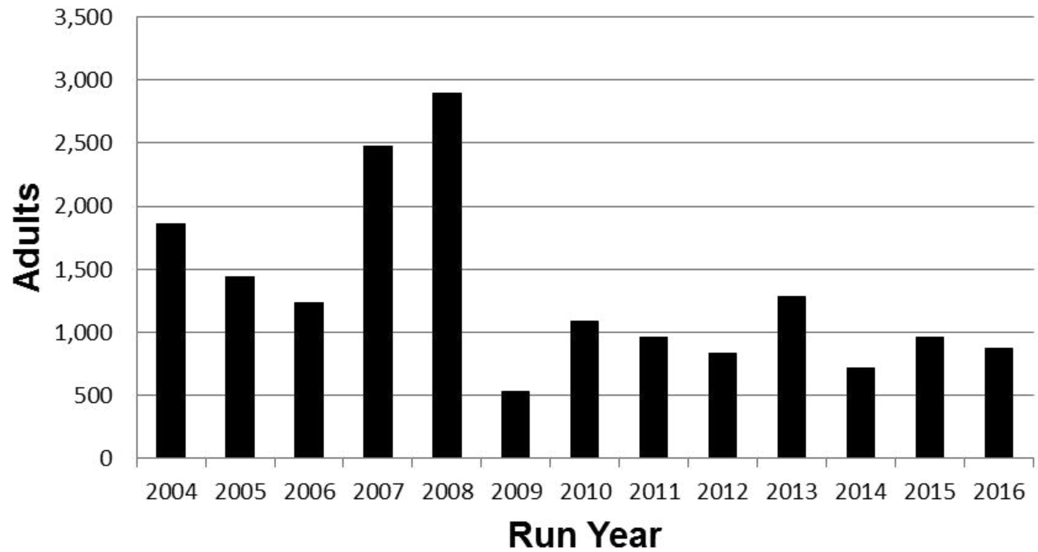
Figure 2-2. Natural-Origin Adult Returns to Nisqually River

[6] Outmigrants are juveniles that leave the river system for the ocean as measured at the WDFW trap at river mile 12.8 (river kilometer 20.6).

[7] Adult recruits are Chinook produced from a brood year (from one year's spawners). Adult recruits are measured as the number of adults returning to the Nisqually River (includes marine survival and preterminal harvest) or number that would have returned absent preterminal harvest (just marine survival).

[8] Unmarked natural-origin Chinook in the fishery and escapement are estimated by subtracting unmarked hatchery-origin from the catch and escapement estimate. The fraction of hatchery-origin without an adipose fin clip or CWT (unmarked) is based on annual adult monitoring at the hatchery ponds (see Nisqually Chinook run reconstruction ISIT file, January 2017 for details).

[9] Data tables and recruit per spawner results are presented in Appendix 1, *Nisqually Chinook Run Reconstruction and Spawner-Recruit Analysis.*



Source: Nisqually Chinook run reconstruction ISIT file (September 2017).

Natural-origin natural spawning escapement has been relatively stable (Figure 2-3) despite declining natural-origin adult runs to the river (Figure 2-2). The percent hatchery-origin in natural spawning (pHOS) in averaged 66% from 2004 to 2016. Since 2013 the pHOS has been less, averaging 44%. The number of hatchery-origin Chinook escaping to natural spawning areas declined beginning in 2013, possibly in response to changes in operation of the fish ladders to the hatcheries and poor survival of hatchery Chinook in some of the years. Beginning in 2013, the fish ladders were kept open at the Kalama and Clear Creek hatcheries for the entire adult migration period to minimize straying to natural spawning. Prior to 2013, the ladders were closed during the first part of the adult migration and then opened only for short periods during the season to meet hatchery broodstock collection needs.

Figure 2-3. Natural Spawning Escapement of Natural-Origin and Hatchery-Origin Chinook

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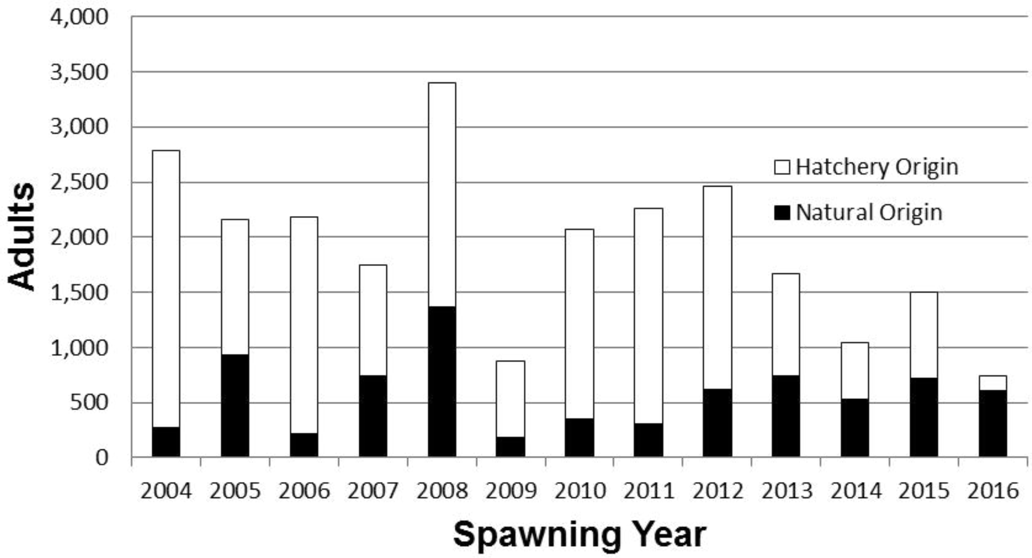


Source: Nisqually Chinook run reconstruction ISIT file (September 2017).

The depressed adult run to the river shown in Figure 2-2 is likely because of a combination of factors affecting freshwater and ocean survival. It does not appear to be caused by low parent spawning escapements (Figure 2-3). Stability in escapement has been mediated by reductions in terminal (in-river) harvest;[10] terminal harvest of unmarked Chinook[11] has decreased since 2009 consistent with terminal harvest objectives described in the *Puget Sound Chinook Comprehensive Management Plan* (Puget Sound Indian Tribes and Washington Department of Fish and Wildlife 2010). FRAM-based reporting of total exploitation rates[12] shows a decrease from approximately 70% in 2008 and 2009 to 50% in recent years, consistent with exploitation rate objectives for the Nisqually River (Figure 2-5). This decrease has been from reductions in the terminal treaty net fishery; recent year (2012 through 2016) terminal rates averaged 27% compared to an average rate of 51% from 2004 to 2011.

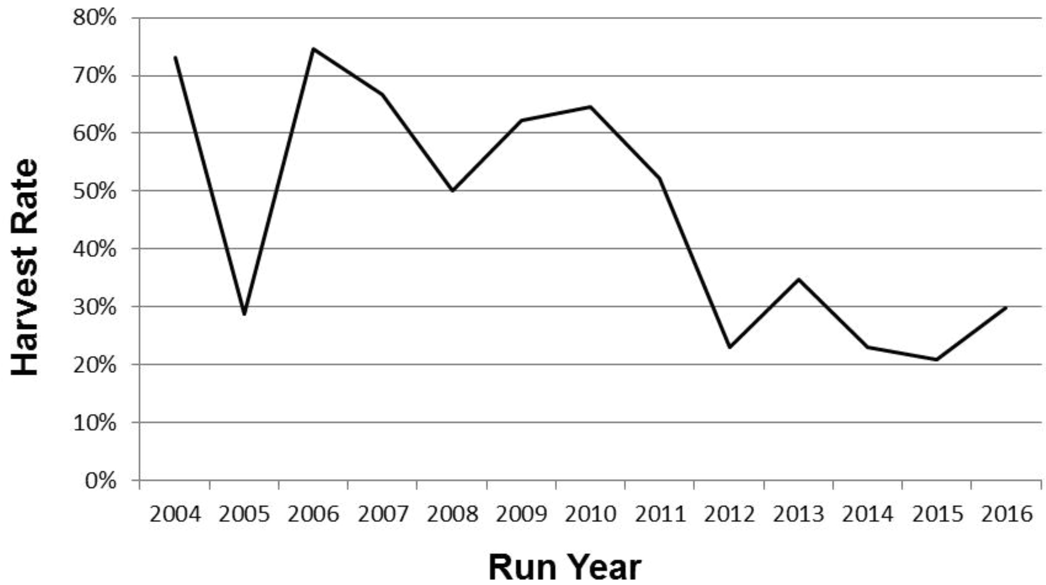
From 2011 to 2015, the average terminal harvest rate among treaty and nontreaty sport fishers was 35.2% (±.12.2 S.D.). Preterminal (fisheries operating outside of the Nisqually River) exploitation rates have tended be stable over the period, averaging 21% and ranging from 17 to 24% (Figure 25).

Figure 2-4. Nisqually Treaty Net Harvest Rates on Unmarked Chinook

[10] The harvest rate is the number of Nisqually fall Chinook harvested in the Nisqually treaty net fishery divided by the number of adults entering the Nisqually fishery (i.e., annual catch divided by annual run to the Nisqually River after preterminal fishery impacts).

[11] Most hatchery fish are visually marked by clipping the adipose fin. However, for purposes of monitoring mark-selective fisheries, some are tagged with a code-wire tag but with no visual mark. In addition, marking has an approximate 95% success rate. Therefore, unmarked Chinook comprise mostly natural-origin Chinook but with a small percentage of unmarked hatchery fish. The incidence of unmarked, hatchery–origin adult Chinook in the terminal run is estimated from adult sampling for marks at the Clear Creek and Kalama Creek hatcheries.

[12] Exploitation rate is the number of Chinook removed by a fishery divided by the total annual number of fish vulnerable to all fisheries. Preterminal and terminal rates are comparable as they are both based on the annual run of Chinook returning to the Nisqually River.

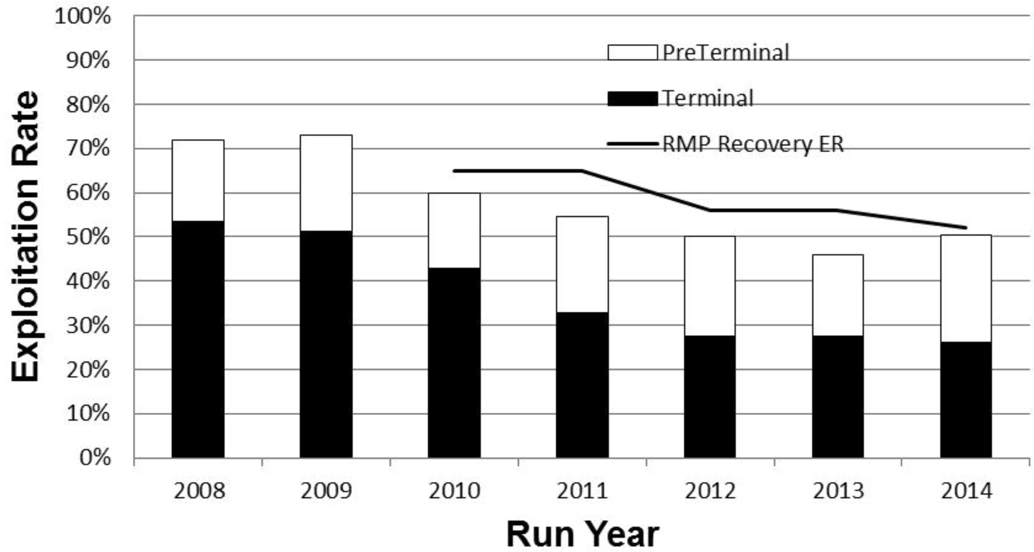


Source: Nisqually Chinook run reconstruction ISIT file (September 2017)

Figures 2-6 and 2-7 depict Nisqually fall Chinook freshwater natural production as indicated by annual juvenile abundance and juvenile recruits per parent spawner.

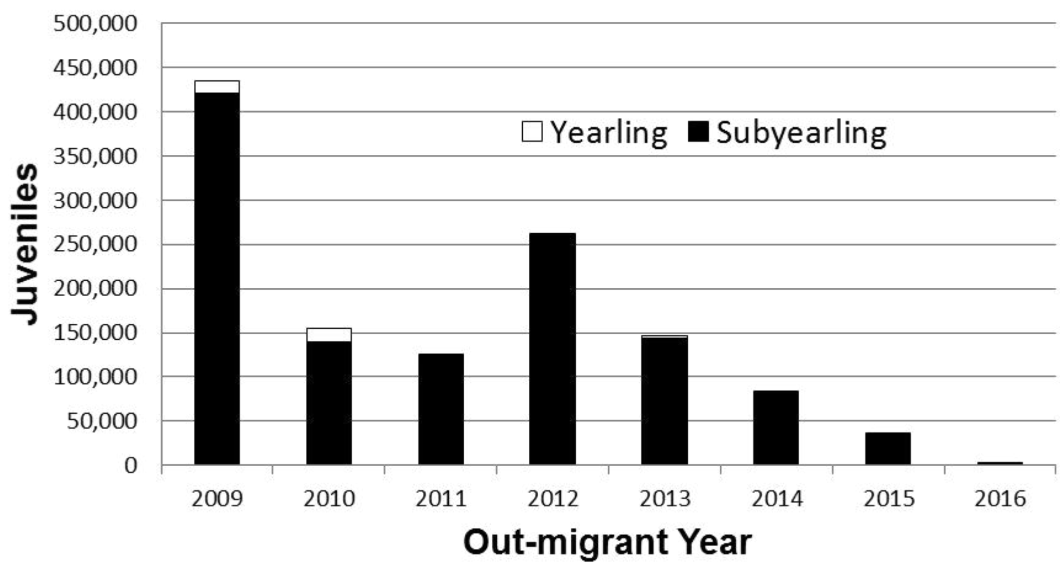
Estimated annual natural production of juvenile Chinook (subyearling and yearling), estimated by WDFW since 2009, in terms of outmigrant juveniles at RM 12.8, has varied from less than 3,000 fish in 2016 to over 400,000 fish in 2009 (Figure 2-5). Subyearling Chinook are progeny from the previous fall natural spawning escapement and yearling Chinook are from natural spawning 2 years prior. The high estimated abundance in 2009 of subyearlings followed the highest estimated natural spawning escapement of nearly 3,500 Chinook in the fall of 2008 (Figure 2-2). The extremely low juvenile abundance in 2016 was the likely result of poor in-river environmental conditions during adult migration and spawning in the parent year (fall of 2015). In the fall of 2015, Nisqually River water temperatures exceeded 20 degrees Celsius (°C) during the first half of the adult migration. A thermal barrier in the Centralia Diversion Dam reach just upstream of the WDFW outmigrant trap location affected upstream movement of migrating Chinook.

Figure 2-5. FRAM-Based Annual Exploitation Rates on Unmarked Nisqually Chinook



Source: Post Season ER NEW BP run date January 24, 2017 Craig Smith, NIT

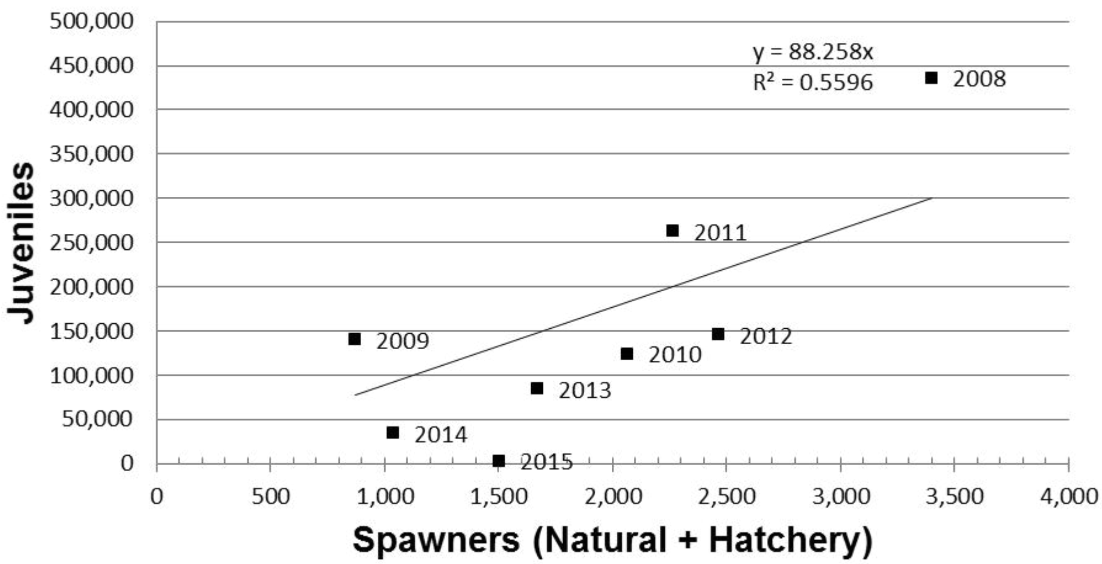
Figure 2-6. Estimated Annual Juvenile (Subyearling and Yearling) Chinook Abundance at RM 12.8



Source: WDFW Klungle et al. in prep

Juvenile recruits per spawner as estimated by the number of subyearling and yearling juveniles divided by the number of naturally spawning Chinook (hatchery- and natural-origin), has varied from a low of 2.0 recruits per spawner from the 2015 brood year to 150 recruits per spawner from the 2009 brood year (Figure 2-7). The number of juvenile recruits per spawner from the Nisqually River watershed was low in all years when compared to the Skagit River, a watershed with an abundant Chinook population and long-time series. Zimmerman et al. (2015) reported 270 to 1,230 outmigrants per female spawner. Assuming a 1:1 sex ratio for Nisqually River Chinook, the number of juvenile recruits per female spawner ranged from 4 to 300, with an average across all years of 153 juveniles per female spawner.

Figure 2-7. Number of Juvenile Recruits (Subyearling and Yearling) per Spawner (brood years shown)

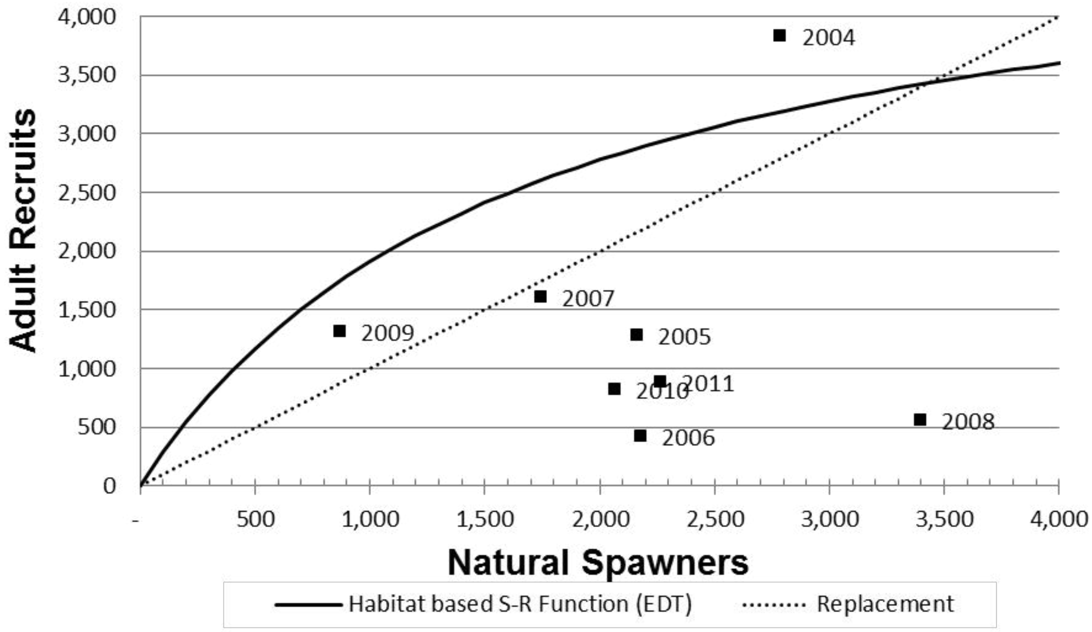


Source: NIT and WDFW data in Nisqually Chinook run reconstruction ISIT file (September 2017)

Figure 2-8 depicts Nisqually Chinook natural spawner to adult recruits back to the Nisqually River. In this case adult recruits are the number of Chinook returning to the Nisqually River by brood year.[13] Annual run to the river was allocated to brood year based on marine age data for unmarked Chinook provided by the Tribe. Adult recruits per natural spawner has varied from 0.2 to 1.5 from 2004 to 2011. Adult recruitment exceeded the replacement line (recruits per spawner greater than 1.0) in just 2 brood years (2004 and 2009). An assessment of habitat potential using the Ecosystem Diagnosis and Treatment (EDT) model suggests observed population performance is much less than habitat potential for the watershed.

Figure 2-8. Natural-Origin Adult Recruits per Spawner (Brood Years Shown), Solid line is Current Condition Habitat Potential from the Ecosystem Diagnosis and Treatment (EDT) Model

[13] Future analyses will evaluate the number of adult recruits per spawner including Nisqually Chinook harvested in preterminal fisheries.



Source: NIT and WDFW data in Nisqually Chinook run reconstruction ISIT file (September 2017)

In summary, productivity and abundance trends for natural production suggest the following.

- Abundance of natural-origin adult runs to the river were relatively strong in 2007 and 2008, but tended to be less than 1,000 Chinook from 2009 to 2015. Hatchery practices and preterminal harvest have not meaningfully changed across this time and therefore the reduction in natural-origin terminal run is not likely to be due to genetic effects from the hatchery program.
- Juvenile outmigrant production was relatively stable at over 100,000 fish from 2009 to 2013, but declined sharply in recent years. The extremely low juvenile outmigrant abundance in 2016 suggests poor adult spawning success caused by the exceptional drought conditions in 2015.[14]
- Juvenile outmigrant production data do not suggest a density-dependent effect on survival; in other words, the data suggest the system can accommodate greater freshwater production. Accordingly, higher escapement should result in higher juvenile production upstream of RM 12.8, assuming favorable environmental conditions in the river.
- Juvenile productivity data suggest the number of juveniles per spawner is low relative to other more productive populations in Puget Sound such as the Skagit River.
- Survival of adults back to the river (combined effects of marine survival and preterminal harvest) is highly variable with indications that the 2009 brood year (2010 subyearling outmigrants and adults returning in 2012 and 2013 at ages 3 and 4, respectively) survived at a higher rate compared to other years.

[14] Temperatures in excess of 20 degrees Celsius (°C) were measured throughout the mainstem Nisqually River.

- Fry migrating in late January to mid-February represent a majority of the migrants in some years. More study is needed to better understand habitat use by juvenile Chinook in the Nisqually delta. Otolith microstructure analysis has found that Chinook that migrate downstream as fry and then rear in the delta as parr from May to June before migrating to sea survive better than other life histories (Lind-Null et al. 2009).
- Adult recruits per spawner have been less than replacement in most years. Low adult to adult productivity is a combination of relatively low freshwater productivity of the population (average of 153 juveniles per female spawner) and low survival of juveniles in the Nisqually delta and marine environments.
- Composition of hatchery-origin Chinook in natural spawning was high prior to 2013. What effect this may have on observed productivity of the population has not been evaluated, but should be considered a factor.

Reevaluation of the 2011 Stock Management Plan

Trends in abundance of natural-origin adult returns to the Nisqually River, spawning escapement, and juvenile production all indicate that natural-origin production is less than the potential of the system. Current natural productivity (juvenile recruits per spawner and adult recruits per spawner) and expected adult abundance over the short term reflect a population that is severely depressed relative to the habitat potential. The long history of out-of-basin transfers of hatchery fish into the Nisqually and multiple generations of hatchery propagation, combined with high pHOS, lead to the conclusion that the genetic make-up of the current Nisqually Chinook is significantly different than the native stock suggesting low fitness may be a significant factor affecting performance of the population.

Since the weir was no longer a viable tool to move the stock into local adaptation and future adult abundances are well below levels necessary to manage for local adaptation, the objectives contained in the 2011 plan around pHOS management and PNI had to be re-evaluated based on these current populations conditions.

In 2016, the co-managers began a new planning process focused on moving the Nisqually population toward local adaptation using the HSRG (2014) recovery phase framework. The co-managers concluded the current depressed status of the population and projected low future adult run sizes based on low juvenile abundance from 2014 to 2016 (less than 100,000 annual outmigrants) would require stepping back from moving into the local adaptation phase of the framework identified in the 2011 plan and refocus efforts on rebuilding natural production (colonization phase of the framework). The co-managers concluded the abundance of natural-origin Chinook salmon returning to the river was too low to manage for PNI (reduce pHOS and integrate broodstock with natural-origin) given escapement and harvest objectives. The technical recommendation was to prioritize rebuilding the natural origin component through a strategic colonization approach. This recommendation delays the transition to local adaptation, but does not appreciably erode its success because of the long history of out-of-basin hatchery stocking in the Nisqually River and high hatchery contribution to natural spawning.

The recommendation was based on past information that indicates natural production of Chinook could exceed 400,000 juveniles. Therefore, there may be potential to increase natural population abundance by increasing spawner abundance (without regard to composition of hatchery or natural origin) to a point where either natural production is sufficient to transition to local adaptation or there is evidence of density dependence limiting natural production. If the natural population could be increased, the likelihood of obtaining PNI objectives would improve.

The hypothesis that the Nisqually River may have greater potential to produce natural-origin juvenile and adult recruits than had been previously documented is based on the following.

- A generally positive relationship between total spawners and juvenile recruits (Figure 2-6) indicating the watershed is not at capacity.
- An assumption that there is underutilized capacity in the Nisqually estuary and there is now otolith-based evidence that migrants that spend appreciable time in the Nisqually estuary contribute disproportionately to adult returns (Lind-Null et al. 2009; NIT and U.S. Geological Survey unpublished data).
- Estimates of habitat potential for freshwater production and estimates of productivity and capacity of the much improved Nisqually River estuary to support juvenile Chinook.

In February 2017, a Nisqually technical work group was convened to develop a technical approach to colonization that would help understand population potential for natural production and rebuild abundance to allow the transition to local adaptation. A substantial unknown is whether the population is sufficiently productive to sustain natural production after transiting to local adaptation and active supplementation of natural spawning with hatchery adults is terminated.

The Nisqually technical work group agreed that, based on the HSRG recovery phase framework, population status is in the colonization phase and management priorities should focus on substantially increasing the number of naturally spawning adults throughout the watershed to improve natural production and identifying monitoring and evaluation efforts to better understand the natural production potential and use of the watershed and biological triggers for transitioning through the recovery phases. This new stock management approach is described in detail in Chapter 3, *Phased Recovery Approach*.

Continuing Habitat Efforts and Watershed-Wide Issues

Since the implementation of the original Nisqually Chinook Recovery Plan (Nisqually Chinook Recovery Team 2001), major habitat restoration initiatives have been accomplished in core areas and efforts have continued to protect existing habitat and evaluate restoration activities. Major habitat restoration initiatives have been completed in the Nisqually delta and the two primary tributaries important for Chinook, the Mashel River and Ohop Creek. Habitat protection efforts continue to advance, ensuring that existing high-quality habitat will remain and the quality and quantity of Nisqually salmon habitat will increase over time. Habitat monitoring and evaluation efforts have generated new insights into the status of core habitat-forming processes in the watershed, which led to the development of large-scale restoration and protection initiatives. However, Nisqually Chinook have the longest migration through Puget Sound of all the core populations in the ESU, making their successful recovery dependent on habitat recovery throughout the region.

The *Nisqually Chinook Recovery Plan* (Nisqually Chinook Recovery Team 2001) contained an action plan that outlined specific restoration and protection priorities. The action plan, which was guided by EDT model results, identified the following general priority areas: the Nisqually delta, portions of the Nisqually mainstem, Ohop Creek, and the Mashel River. Work on actions listed

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in the 2001 plan is ongoing to refine the habitat priorities through research, assessments, monitoring, and evaluation. For example, when the 2001 plan was developed, information was lacking on how Nisqually Chinook utilize the nearshore environment and about the condition of the nearshore habitat. Juvenile Chinook sampling since then has indicated that the nearshore areas adjacent to the Nisqually delta are important for Chinook rearing and migration. Additionally, several nearshore assessments have been completed, including the Nisqually to Point Defiance Nearshore Habitat Assessment. South Sound Nearshore habitat protection and restoration is now considered to be a high priority. The continued evaluation of key physical processes in the watershed have resulted in the identification of critical large-scale initiatives that need to occur for recovery of essential salmon habitat.

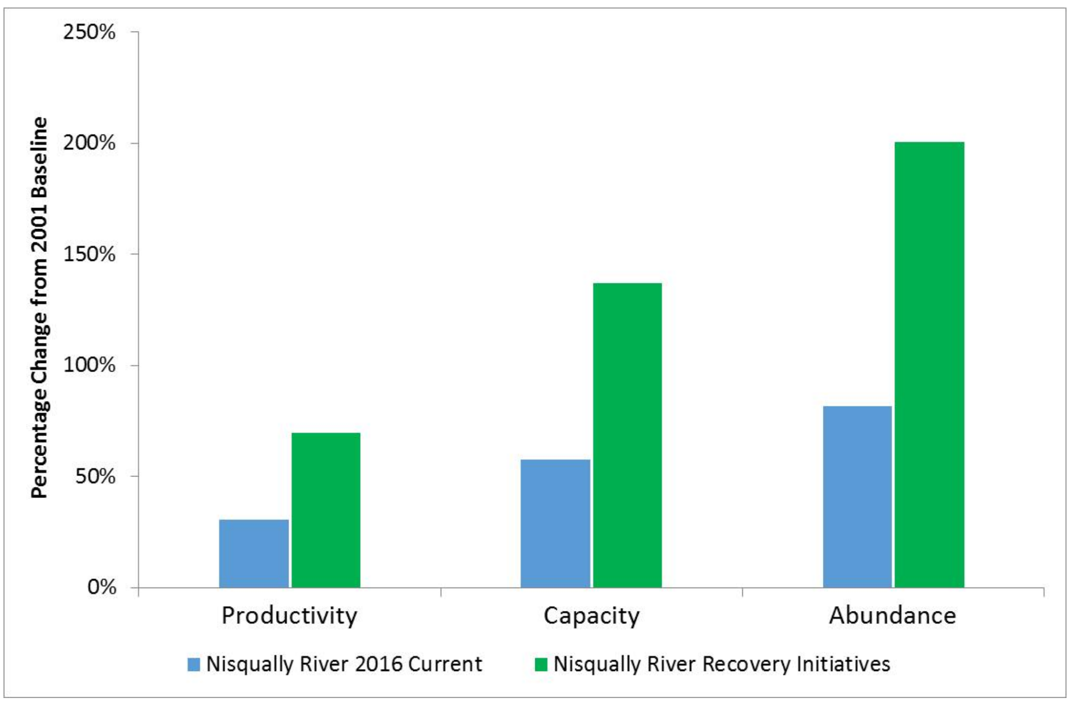
The return of tidal inundation to over 750 acres of the U.S. Fish and Wildlife Service Billy Frank Jr. National Wildlife Refuge at Nisqually in fall of 2009 was the crowning moment in the effort to protect and restore the Nisqually delta. The refuge project complemented three earlier restoration projects completed by the Tribe to restore over 900 acres of the delta, representing the largest tidal marsh restoration project in the Pacific Northwest and one of the most significant advances to date toward the recovery of Puget Sound. However, extensive post-restoration research by the Tribe, U.S. Geological Survey, and others identified that altered physical processes (river flow control, reduced sediment inputs) and the 100-year history of subsidence since initial diking threaten to undermine the recovery trajectory of the Nisqually delta (Curran et al. 2016). Especially as sea level rises due to climate change. To alleviate the sediment deficit, the routing of sediment needs to be improved through Interstate 5 and more sediment needs to make it through Alder and LaGrande Reservoirs. These projects will cost more than $1 billion but are absolutely critical for the long-term recovery of Chinook. New analyses have pointed to impaired watershed processes in the upper watershed, which also need to be addressed (citation pending).

The Mashel River is the most important tributary in the Nisqually watershed, a relatively "tributary poor" system, for Chinook and steelhead recovery identified in both the *Nisqually Chinook Recovery Plan* (Nisqually Chinook Recovery Team 2001) and the *Draft Nisqually Winter Steelhead Recovery Plan* (Nisqually Steelhead Recovery Team 2014). The Mashel watershed has been decimated by commercial forestry operations for over a century. To date, recovery actions in the Mashel have consisted of constructing engineered log jams and land acquisition in the lower Mashel River. This large-scale, multimillion-dollar effort has been extremely successful at increasing instream habitat diversity, restoring riparian zones, and reducing channel confinement. However, continued and future degradation of watershed processes in the upper watershed threatens to negate the progress already made and makes recovery of Nisqually salmon improbable. In response, the Nisqually Land Trust, Nisqually Indian Tribe, Nisqually River Council, and others have launched the Nisqually Community Forest Initiative. The goal of the initiative is to purchase much of the privately held timberlands in the upper Mashel and manage them for long-term ecosystem services recovery and sustainable local economies. This initiative will cost nearly $200 million and take decades to come to fruition.

The location of the Nisqually River in South Puget Sound makes the Nisqually fall Chinook stock arguably the most dependent on the Puget Sound ecosystem out of all the 27 stocks listed in the Puget Sound Chinook ESU. Juvenile Nisqually Chinook need functional nearshore habitat, as well as offshore-based prey resources to feed, grow, and survive during their lengthy migration to the Pacific. Additionally, returning adults must have forage fish throughout Puget

Sound to put on growth essential for the arduous river migration and spawning stages of their life history. The cumulative effect of marine mammal predation on juveniles and adult Nisqually Chinook is yet another impact magnified by their lengthy traverse through the Puget Sound. The effort to protect and restore salmon habitat in the Nisqually River has been incredibly successful in the face of persistent human population pressure, insufficient funding, and wavering political will. While the current condition of the Nisqually watershed is more conducive to salmon recovery than it was 20 years ago, the need for massive investments in watershed process–based recovery still remains. EDT modeling indicates that the improvements made since implementation of the 2001 plan have resulted in increases of 31%, 58%, and 82% in productivity, capacity, and abundance, respectively (Figure 2-9). However, even larger jumps in Nisqually Chinook population performance can be expected from successful implementation of large-scale habitat initiatives, including recovery of sediment delivery and channel migration in the Delta and changing management of the forestland in the Mashel watershed to focus on ecosystem services and watershed processes (Figure 2-1). The long road to a viable, self-sustaining, and productive Nisqually Chinook population starts at the watershed but will ultimately depend on sustained and aggressive actions to recover the Puget Sound ecosystem.

Figure 2-9. Modeled Improvements in Nisqually Chinook Habitat Potential Since Implementation of the 2001 Recovery Plan and Projected Improvements with Future Projects



Source: Ecosystem Diagnosis and Treatment model run September 20, 2017

Chapter 3
Phased Recovery Approach

This stock management plan uses a phased recovery approach, based on HSRG (2014), to achieve the conservation and harvest goals for Nisqually fall Chinook.[1] The phased recovery approach provides a science-informed, policy-directed framework that balances harvest and conservation. The framework is intended to help organize the following.

- The three elements of recovery: habitat restoration and protection, harvest management, and population productivity.
- Interim policies to guide harvest, hatchery management, and conservation as habitat recovers and population productivity and abundance improves.
- A process that is responsive to uncertainty in the plan and expected variability in recovery progress.

The framework provides a means to balance the goals of recovery and rate of progress and compliance with treaty rights, with a strong commitment to utilizing the best available information in an informed adaptive management process. The framework includes all elements of recovery essential to complying with treaty rights, interim policies to guide annual decisions to make progress toward recovery and comply with treaty rights, and a recognition of uncertainty and variability in population status that will affect progress to recovery and implementation of treaty rights.

Hatchery Scientific Review Group Framework

HSRG (2014) defines four biologically based phases for “restoration and rebuilding” of salmon populations: 1) preservation, 2) re-colonization, 3) local adaptation, and 4) full restoration. This stock management plan starts with the re-colonization phase (renamed Colonization phase for this plan) and continues through full restoration (renamed Viable Population phase for this plan). These three phases, the ecological conditions characterizing each phase, and the primary objective during each phase, as defined by HSRG and revised slightly to better reflect the Nisqually population, are described in Table 3-1. These phases represent milestones toward recovery and mark a shift in population status as well as priorities and policy direction (i.e., harvest, conservation, and maintenance of progress).

Table 3-1. Ecological Conditions and Plan Objectives Associated with the HSRG Recovery Phases

[1] Chapter 1, *Introduction*, presents the overarching goal for Chinook recovery. The harvest and conservation goals and objectives are presented in full in the *Nisqually Chinook Recovery Plan* (Nisqually Chinook Recovery Team 2001).

Recovery Phase	Ecosystem Conditions[a]	Plan Objectives
Colonization	Underutilized habitat available through habitat restoration and improved fish access to habitats.	Repopulate vacant, underutilized, and restored habitats to increase natural production, abundance, and diversity of the population through the supplementation of natural spawning with hatchery-origin adults.
Local Adaptation	Habitat capable of supporting abundances that minimize risk of extinction, as well as tribal harvest needs; population performance sufficient to promote genetic and life-history diversity.	Meet and exceed abundance thresholds for natural-origin spawners; reduce hatchery influence on the population to promote adaptation to natural habitat conditions in the Nisqually River basin and deep South Sound; increase fitness, reproductive success, and life history diversity.
Viable Population	Habitat restored and protected to allow full expression of abundance, productivity, life-history diversity, and spatial distribution; population performance (abundance, productivity, and diversity) sufficient to meet long-term sustainability of population.	Maintain a productive, resilient, spatially and temporally diverse population that is taking full advantage of the available habitat with minimal hatchery supplementation.

Source: Hatchery Scientific Review Group 2014

VSP attributes such as productivity and abundance and measurable metrics, or indicators, of those attributes—such as spawner abundance and composition, and natural-origin adult recruits and recruitment rates—are monitored and evaluated to understand the characteristics of the population and the success of management actions. Biological targets describe the population characteristics—in terms of desired conditions for a set of VSP attribute indicators—that must occur for the population to function within each recovery phase and to transition from one phase to the next.

Annual management decisions are related to harvest, broodstock collection, hatchery release, and removal of hatchery-origin adults from natural spawning. Annual management targets, representing the desired outcomes of these decisions, are developed annually based on predefined decision rules[2] and on annual run forecasts. Decision rules and annual management targets change as the population transitions through the recovery phases. Implementation of the annual preseason and in-season hatchery and harvest management actions are important to respond to uncertainty and variation in run size.

Chapter 4, *Implementation Plan,* describes the VSP attributes, indicators of VSP attributes, biological targets, and management targets specific to this stock management plan. Chapter 5, *Monitoring Tools and Objectives*, presents the monitoring programs that will be implemented under this plan to track progress toward these targets. Monitoring results are reviewed and evaluated annually to identify successes and failures of management actions during the previous year and to inform targets and management decisions for the upcoming year, as described below under *Adaptive Management Framework*.

[2] Predefined decisions rules, which reflect policy priorities, are established to guide the development of management targets for harvest, broodstock collection, hatchery release, and removal of hatchery-origin adults from natural spawning

Local Adaptation Approach

This section describes guidance from HSRG (2014) to promote local adaptation of salmonids to the natural environment. This guidance was used to develop the implementation plan for the Local Adaptation phase, presented in Chapter 4, *Implementation Plan*, including biological targets, management targets, and recommendations on how information will be used to inform program planning and adaptive management for Nisqually Chinook.

The overarching strategy identified by HSRG (2014) during the Local Adaptation phase is to manage hatchery programs to not impede adaptation to existing and changing (e.g., habitat restoration and climate change) natural conditions. This means that fitness-related traits (e.g., adult spawn timing) must be determined by the natural environment experienced by the population and not the hatchery environment.

However, a key assumption for local adaptation is natural-origin spawners are sufficiently abundant to assure the population will persist and grow with reduced or absent hatchery supplementation. Thus, the Colonization phase is an important step to rebuilding natural production. However, it does not address the potential underlying risk of low productivity of the population due to fitness effects hypothesized by HSRG. If fitness is a significant factor affecting productivity of the population, then moving as quickly as feasible to the Local Adaptation phase is advisable.

Hatchery Influence

Many of the traits related to reproductive success (e.g., spawn timing, age-at-maturity, and fecundity) can be influenced by hatchery propagation (Carlson and Seamons 2008). Hatchery-origin salmonids spawning in nature are often observed to produce fewer adult offspring than natural-origin fish due to both environmentally induced characteristics (e.g., choice of spawning location as a consequence of release location and homing) and domestication selection affecting heritable traits (e.g., spawn timing) (Christie et al. 2014). Moreover, these traits are heritable. Even hatchery programs that are operated using benign spawning techniques, such as those described by Campton (2004), result in domestication selection through relaxation of natural and sexual selection during spawning (Quinn 2005) and can affect reproductive success (i.e., fitness) of future generations in the wild. The consequence is that the fitness of future generations may be impaired depending on the degree of artificial selection during hatchery propagation and the heritability of maladaptive traits.

There is evidence that hatchery propagation, even for one or two generations and when broodstock is collected from wild fish populations, can result in lower fitness of hatchery-reared fish in nature than wild fish (Araki e al. 2008). These studies are for salmonids with long freshwater residence and may be subject to additional domestication selection while in the hatchery. Berejikian and Ford (2004) suggest it is reasonable to assume domestication selection may be less for salmon with a short freshwater period (i.e., subyearling Chinook). Nevertheless, it is reasonable to assume that fitness of Nisqually Chinook in the wild is much less than the ancestral population for two reasons: Chinook in the Nisqually River are derived from an out-of-watershed hatchery stock[3] and the stock has been largely a hatchery stock with no attempt to include gene flow from natural-origin adults.[4]

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[3] The most recent stocking of an out-of-watershed hatchery stock was in 1996.

[4] Monitoring to evaluate production potential of the existing hatchery-dominated population and possibly the relative reproductive success of hatchery-origin adults spawning in the wild compared to natural-origin adults will

Annual management targets for spawning composition and natural-origin in hatchery broodstock during the Local Adaptation phase are based on a single-trait phenotypic fitness model developed by Ford (2002). The fitness model predicts a shift in a hypothetical trait value toward an environmental optimum representing the hatchery and natural environments. The fitness model includes assumptions of selection strength, trait heritability, and trait variance. Application of the Ford model to Nisqually Chinook for the current condition predicts a mean population trait value strongly shifted toward the hatchery optimum, suggesting a low current fitness condition. This does not take into account that Nisqually Chinook may be further removed from the natural optimum because the historical population was extirpated and replaced with an out-of- watershed hatchery-derived stock.

The Multi-Population PNI (MP-PNI) model developed by Craig Busack with NOAA Fisheries[5] was used to evaluate program assumptions, develop gene flow guidelines, and set annual management targets during the Local Adaptation phase of this effort. Assumptions used in the model included a two part natural population (natural spawning downstream and natural spawning upstream of the Centralia Diversion Dam), an integrated hatchery component (Kalama Creek Hatchery), and a "stepping-stone" hatchery program (Clear Creek Hatchery and McAllister Springs release).[6]

Modeling Foundation for Local Adaptation Management Targets

Direct measures of genetic effects of hatchery propagation on wild population fitness are difficult to obtain and beyond the objectives of this stock management plan. Monitoring annual management targets for the following indicators of gene flow is a reasonable substitute.

- pHOS: Annual proportion[7] of adults spawning in nature that are of hatchery origin.
- pNOB: Annual proportion of hatchery broodstock that are natural-origin adults from the donor population component.

Management targets for these indicators and for the resulting estimate of the PNI[8] of the composite population will be one of the indicators used to monitor progress toward achieving a population adapted to the environmental conditions in the Nisqually River watershed and Puget Sound and will be updated as new science and information becomes available.

be conducted during the Colonization phase. However, the relative fitness of hatchery-origin Chinook cannot be compared to locally adapted wild Nisqually fall Chinook because the wild population no longer exists.

[5] The MP-PNI model is a multi-population extension of the Ford model that links several population components through assumptions of gene flow. In the Nisqually case, natural-origin Chinook are used in the integrated program broodstock (pNOB) and the stepping-stone program broodstock is linked to the natural population through the use of returns from the integrated program.

[6] The plan will be updated based on new data and information consistent with the check points described in the Colonization Phase. The hatchery strategy during local adaptation, including inclusion of a stepping-stone program, is based on current scientific thinking and data, and the assumption that the magnitude of natural-origin spawners relative to the hatchery component of natural spawners will be sufficient at the transition from colonization to local adaptation to achieve a PNI greater than 0.50 given the hatchery production and harvest objectives. This strategy will be reviewed at the point of transition to local adaptation to ensure the strategy that is adopted reflects best science and information at that time.

[7] Monitored separately for the natural populations upstream and downstream of the Centralia diversion dam.

[8] PNI is an indicator of the degree to which the hatchery and natural environments influence selective pressures in the composite natural population upstream and downstream of the Centralia diversion dam.

The MP-PNI model is used to calculate the equilibrium PNI, which is the PNI value that over multiple generations of modeling no longer changes with subsequent generations.[9] Annual estimates of equilibrium PNI based on the estimated pHOS and reported pNOB in the integrated program broodstock will be the basis for monitoring progress toward local adaptation.

PNI and the resulting prediction of fitness effects are based on PNI values varying from 0.0 to 1.0, where *PNI = 0.0* or *PNI = 1.0* imply that the genetic structure and mean phenotypic values for the composite population are influenced only by the hatchery or natural environment, respectively. Theoretically, a PNI value greater than 0.5 indicates that selective forces in the natural environment will have a greater influence on the population than selective forces in the hatchery environment.

In the equation for PNI, pHOS is based on census data of the proportion of hatchery-origin spawners (correction factor of 1.0). Monitoring programs described in Chapter 5, *Monitoring Tools and Objectives*, provides sufficient and unbiased sampling of spawners and accurate identification of hatchery- and natural-origin spawners to calculate annual PNI estimates.

A census-based estimate of pHOS implies a relative contribution of hatchery-origin adults spawning in the wild of 1.0, meaning hatchery-origin adults have the same contribution to the next generation as natural-origin adults when spawning in the wild. The Nisqually technical work group decided to not include a correction factor for hatchery-origin spawners. A study plan to evaluate a reproductive success of hatchery-origin spawners relative to natural-origin for Nisqually Chinook is discussed in Chapter 5, *Monitoring Tools and Objectives, Additional Monitoring and Studies*. HSRG (2014) has in some cases applied a correction factor on hatchery-origin adults spawning in the wild to estimate an effective hatchery contribution.

Annual PNI will be estimated by computing the equilibrium point based on the previously described metrics and reported as a running 4-year average to monitor progress toward local adaptation. The 95% confidence intervals for pHOS will be estimated and reported to track the range of possible pHOS and resulting PNI values. The annual PNI estimate will be based on the hatchery broodstock pNOB in the integrated program for the same year.

Equilibrium PNI is a long-term trend (tens of generations) and is used only to indicate a range of possible effects of managing for higher natural influence for multiple generations. The Nisqually technical work group has set a PNI objective of 0.50 at the beginning of the Local Adaptation phase (consistent with a Tier 2 population). Following the transition annual management decisions will attempt to annually increase PNI to achieve a PNI objective of 0.67 (consistent with a Tier 1 population) to move into the Viable Population phase. The higher PNI objective is expected to occur through increased abundance of natural-origin with hypothesized improvements in population performance (productivity and capacity) with predicted increase in fitness and through additional habitat restoration in freshwater, the delta, and nearshore marine areas. Additional management actions to increase PNI to the 0.67 objective are discussed in Chapter 4, *Implementation Plan*.

Adaptive Management Framework

This adaptive management framework establishes the systematic review and evaluation of information to audit performance, challenge key assumptions, guide decisions, and plan activities for the upcoming year (Figure 3-1). The process is formalized in a database and a set of

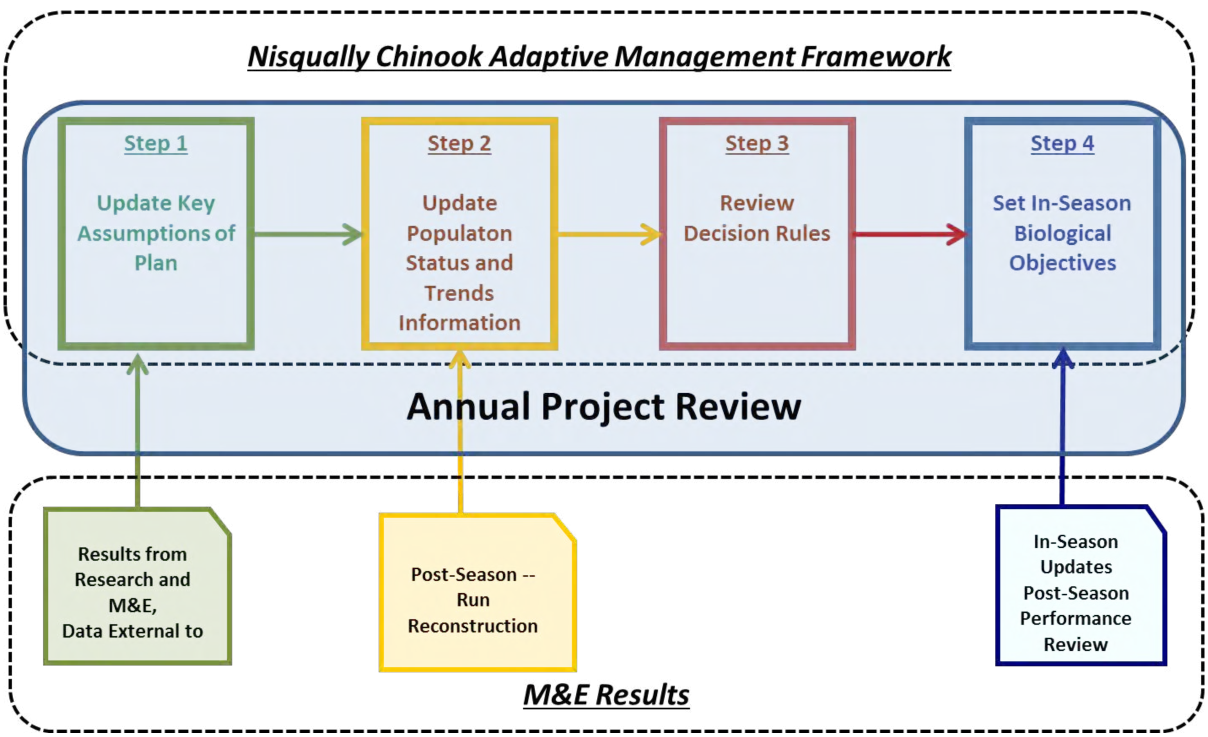
[9] The PNI approximation described by the HSRG (2014) does not account for the stepping-stone program or the differences in gene flow among the natural population components.

management tools that ensure consistency and accountability from year to year (Chapter 6, *Data Management, Record Keeping, and Accounting*).

The 3-day Annual Project Review (APR) convened each year by the co-managers is the cornerstone of the adaptive management framework. The APR is convened to allow the Nisqually Indian Tribe, WDFW, NOAA Fisheries, and other participants to provide updates, review monitoring results, and plan for the upcoming season. The APR includes the following elements.

- Review previous year's performance against management targets and biological targets.
- Update status and trends information, based on post-season run reconstruction and evaluation of monitoring results for VSP attribute indicators and biological targets.
- Update key assumptions, based on monitoring and evaluation results and ongoing research, to ensure a scientifically defensible working hypothesis for recovery.
- Review and apply decision rules for harvest, hatcheries, and escapement using preseason run size projections.
- Review and update biological targets for the coming year to reflect any change in status of the population and for consistency with recovery objectives.
- Update monitoring programs to reflect information needs to evaluate population status, key assumptions, and research questions.
- Develop action plan for next year.

Figure 3-1. Adaptive Management Framework



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In addition to review during the APR, a more thorough data-driven assessment to evaluate assumptions about the productive potential of the stock and the capacity of the watershed and delta and to determine if the management strategies are adequate is described in Chapter 4, *Implementation Plan*.

Adaptive management decisions vary in the degree of policy involvement and the frequency with which they need to be revisited. While overall recovery goals will be reviewed less frequently, management policies guiding fisheries and conservation decisions may need to be reviewed more often, depending on status of the population, environmental conditions, and progress toward recovery. Near-term objectives such as annual management targets, strategies, and implementation will be reviewed annually prior to the fall management season. Finally, the Nisqually technical work group will meet at regular intervals throughout the year to ensure that activities are coordinated among the agencies working toward recovery.

Chapter 4
Implementation Plan

This chapter presents the plan for implementing the phased recovery approach, beginning with the implementation of an 8-year colonization experiment to boost natural production and ending with the establishment of a self-sustaining viable population based on the best available scientific information. It describes the anticipated outcomes of hatchery, harvest, and continued habitat actions on the population through multiple generations. For each recovery phase an approach to the management of harvest, hatchery, and escapement is described.

Table 4-1 presents the VSP indicator characteristics of the population by plan phase. VSP indicators for abundance, productivity, spatial diversity, and life-history diversity are shown for each recovery phase. The indicators describe population characteristics consistent with each phase of the plan and are used to develop decisions rules and evaluate hatchery, harvest, and escapement objectives for each phase. Nisqually Chinook management will shift from the Colonization phase to the Local adaptation phase within 8 years independent of population status. The transition from the Local Adaptation phase to Viable Population phase is expected to occur after multiple generations of management under Local Adaptation and is strongly dependent on achieving habitat recovery objectives for freshwater, estuarine and marine areas as well as expected improvements in population fitness predicted under local adaptation.

The biological characteristics for each recovery phase presented in Table 4-1 will be updated as new information becomes available through VSP indicator monitoring identified in Table 4-2. Monitoring VSP indicators at each phase will inform the update of biological characteristics and management needs of each successive phase.

Table 4-2 describes the indicators identified by the Nisqually technical work group to evaluate population status. Specific monitoring programs are described in Chapter 5, *Monitoring Tools and Objectives, Additional Monitoring and Studies*.

Overview of Phase Goals and Objectives

A brief overview of each phase and rationale for biological characteristics in Table 4-1 is provided below.

Colonization

In addition to rebuilding natural-origin abundance, the Colonization phase is an important first step in the monitoring plan. The Colonization phase is when monitoring methods will be tested and refined, and data collected to be used to evaluate freshwater potential (spawner to juvenile outmigrant capacity and productivity), behavior and survival of juveniles in the delta, and juvenile to adult survival back to the river.

During the Colonization phase, management actions are to increase adult natural spawning with no regard to composition. The objectives are to increase juvenile outmigrant abundances and corresponding adult returns. Current adult mean annual natural-origin escapement abundances are low, with low forecasts for the next several years based on number of juvenile outmigrants in recent years. During colonization, natural spawning will be supplemented with hatchery-origin adults. The Nisqually technical work group hypothesized this action will result in higher annual juvenile abundances and higher annual natural-origin returns to the Nisqually River.

Productivity, as measured both by juvenile outmigrants per spawner and adult recruits per outmigrant and per spawner, will be evaluated for the presence of an asymptote in outmigrants per spawner (an indication of freshwater capacity constraints) and adult recruits per outmigrant (an indication of delta and early marine capacity constraints). Evidence of an asymptote at higher natural spawning for either stage would reflect an upper bound to natural spawning abundance, which will be used to refine escapement objectives during local adaptation. Adult monitoring for natural spawning abundance and distribution, as measured by number of adults spawning downstream and upstream of the Centralia Diversion Dam, in tributaries, and composition (hatchery-origin/natural-origin), will be evaluated to determine effectiveness of adult supplementation actions and habitat potential.

The Colonization phase will be when several key components of the plan are developed and tested. An adult trap in the Centralia Diversion Dam Fish Ladder at RM 26.2 will be installed and tested. The trap will be used to enumerate adult Chinook returning to the upper basin during the Colonization phase, and to remove hatchery-origin and collect natural-origin broodstock during the Local Adaptation phase. Although objectives during colonization do not include reducing hatchery-origin contribution to natural spawning, actions to manage hatchery-origin contribution to natural spawning will be evaluated during the Colonization phase, including moving 1.0 million Chinook from the Clear Creek hatchery release to McAllister Springs and testing fishing methods to differentially harvest hatchery-origin Chinook in the Nisqually treaty fishery. These measures will be important during the Local Adaptation phase.

Local Adaptation

Management actions during local adaptation are intended to meet and exceed abundance thresholds for natural-origin spawners; reduce hatchery influence on the population to promote adaptation to natural habitat conditions in the Nisqually River basin and deep South Sound, improve reproductive success of the population and increase spatial and life history diversity of the population.

A brief description of each population metric in Table 4-1 under local adaptation and a rationale for the range of values are provided below. Results from the colonization experiment will be used to update these population characteristics for the Local Adaptation phase.

The anticipated population characteristics for the Local Adaptation phase in Table 4-1 are set broadly to support a transition to local adaptation within eight years. They characterize the expected response from the colonization experiment and the low end of the ranges are generally based off of the high end of past population performance, reflecting current habitat potential and ability of the population to take advantage of the habitat. Ranges for productivity characteristics consider effects of density dependent factors. Freshwater and delta productivity indicators may be lower with higher abundances because of density effects on survival.

During the Local Adaptation phase the natural-origin adult spawning escapement would range from 1,500 to 3,400. Escapement targets will be refined utilizing monitoring results during the Colonization phase in order to optimize natural production. The transition to the Viable Population phase will occur when the 5-year running average of natural-origin spawning escapement exceeds 3,400 adults. The 3,400 Viable Population spawner abundance target is the high productivity planning target in the Puget Sound Salmon Recovery Plan (National Marine Fisheries Service 2006). The 1,500 adult natural spawning escapement is consistent with the high end of observed run sizes (a Nisqually River run greater than 2,200 adults in 2007 and 2008; see Figure 2-2).

The outmigrant abundance during the Local Adaptation phase is anticipated to range from 250,000 to 400,000 outmigrants, which corresponds with the upper range of observed outmigrant abundances. During the first 5 years of trap operations (2009 to 2013) estimates of abundance ranged from a low of 146,292 Chinook (2013) to a high of 434,969 Chinook (2009) and averaged 224,241 Chinook. Since 2013, juvenile abundance has not exceeded 100,000 outmigrants. The monitoring location for juvenile abundance is upstream of approximately 8 river miles of spawning habitat that would also contribute to natural production. The location for was factored into this range. A watershed-wide juvenile abundance estimate is not possible for the Nisqually River. The Nisqually River delta monitoring program described in Chapter 5, *Monitoring Tools and Objectives, Additional Monitoring and Studies*, will evaluate juvenile timing and densities in the delta, but is not able to provide an estimate of juvenile abundance.

During the Local Adaptation phase, the anticipated range in productivity is 1.5 to 3.0 adult recruits per spawner. Productivity above 3.0 recruits per spawner would trigger the transition to the Viable Population phase. The 3 recruits per spawner represents the high productivity planning target identified in the 2006 Puget Sound Recovery Plan. The low end of this range is the high end of recruits per spawner that have been observed. From brood year 2004 to brood year 2011 productivity ranged from a low of 0.2 recruits per spawner (brood year 2006) to a high of 1.5 recruits per spawner (brood year 2009) and averaged 0.7 recruits per spawner. The level of 1.5 recruits per spawner was met in only one year. However, two major factors were considered when evaluating the historical data. First, the number of parent spawners includes hatchery-origin adults with an unknown contribution to natural production. Second, a majority of the historical recruitment estimates are for brood years prior to major habitat restoration in the Nisqually delta (completed for the 2010 juvenile outmigration).

The range for juvenile freshwater productivity (number of outmigrants [fry, parr, and yearlings] per spawner) during the Local Adaptation phase is anticipated to be from 150 to 300 outmigrants per spawner. The low end value is partially based on historical observations of productivity for the population. Observed productivity has ranged from a low of 2.0 juveniles per spawner (the highly unusual 2015 brood year) to a high of 161 juveniles per spawners (brood year 2009) and has averaged 87 recruits per spawner, excluding 2015. The low estimate for brood year 2015 is likely the result of unusually low flow and warm water temperature in the Nisqually River in the fall of 2015. These factors may have limited upstream movement of adult Chinook salmon through the Centralia Dam diversion reach immediately upstream of the trap location and resulted in pre-spawn mortality. The anticipated range also considered productivity data reported for the Skagit River Chinook. Zimmerman et al. (2015) reported 270 to 1,230 outmigrants per female spawner for Skagit River Chinook. For comparison, assuming a 1:1 sex ratio for Nisqually River Chinook, the number of juvenile recruits per female spawner ranged from 4 to 322, with an average freshwater productivity of 174 recruits per female spawner (again excluding brood year 2015). The Skagit River data suggest a much higher productivity potential for Chinook salmon then currently observed in the Nisqually River that the work group hypothesizes should be achievable for Nisqually River Chinook with improved fitness. The work group also considered that spawner to outmigrant productivity estimates from the Nisqually are based on outmigrant estimates from the trap located at RM12.8 and adult spawner estimates include the entire watershed. Juvenile abundance estimates do not include production from natural spawners below the outmigrant trap. The estimation method for natural spawners does not allow a means to separate escapement abundance above and below the outmigrant trap. The outmigrant trap data will be used to provide a relative estimate of productivity.

The anticipated range of outmigrant to adult survival rates during the Local Adaptation phase was set at 0.75 to 1.0%. Survival rates for brood years 2008 to 2011 (years with complete adult returns) have ranged from 0.1% (brood year 2008) to 0.9% (brood year 2009) and averaged 0.5%. The high survival of outmigrants from brood year 2009 was predominately subyearlings migrating in 2010, immediately after restoration of 750 acres of the Nisqually delta, providing some confidence that future rates with favorable marine conditions will tend to be higher than the data series suggests. In addition, survival through the delta and marine nearshore may be where significant improvements in fitness occur. Over multiple generations of managing for local adaptation juvenile Chinook outmigration timing may shift to later in the season with shifts in spawn timing and selection for later time migration to take advantage of better survival conditions in late winter and spring in the recovering delta and offshore habitats. A survival rate of 1.0% would indicate a transition to the Viable Population phase.

At this time specific numeric targets are not identified for spatial diversity and life history diversity during Local Adaptation. Indicators to characterize spatial diversity include the distribution of adult spawners upstream and downstream of the Centralia Diversion Dam and in the Mashel River consistent with estimated habitat potential. Other indicators are monitoring of juvenile Chinook use of current and restored habitats in freshwater and the delta. The expectation is that management actions will maintain and grow spatial diversity of the population. Adult and juvenile life history traits will be monitored and compared to current patterns. Life history diversity is expected to increase with habitat restoration and expansion. Habitat restoration will increase the complexity of habitat available to Chinook salmon and the potential ways in which adults and juveniles can use that habitat. Indictors for life history diversity may include an increase in variance in life history traits such as age, sex, juvenile life history, and migration and spawning timing.

Viable Population

The anticipated characteristics during the Viable Population phase represent the characteristics of a self-sustaining, locally adapted population. These characteristics will be refined over time as monitoring yields further information about the changing population.

Table 4-1. Anticipated Population Characteristics for Nisqually Chinook within Recovery Phases

VSP Metric[a]	Colonization[b]	Local Adaptation	Viable Population
Adult escapement abundance (natural-origin)	Mean annual escapement exceeds pre-experiment (2012–2020)	>1,500 to 3,400 adults	>3,400 adults
Juvenile abundance (number outmigrants at WDFW outmigrant trap at RM 12.8)	Mean annual juvenile abundance exceeds pre-experiment abundance (2009–2017)	250,000 to 400,000 outmigrants	>400,000 outmigrants
Productivity –juvenile outmigrants per spawner	Observed asymptote in outmigrants per spawner trend, measured over 8 years	>150 to 300 outmigrants per spawner	>300 outmigrants per spawner
Productivity – survival rate from juvenile outmigrant to adult	NA	>0.75% to 1.0%	>1.0%
Productivity –adult recruit to Nisqually River per spawner	Observed asymptote in number of recruits per spawner rate trend measured over 8 years	>1.5 recruits per spawner to 3.0 recruits per spawner	>3.0 recruits per spawner
Spatial diversity – Adult use of natural spawning habitats and juvenile use rearing of habitats	Available habitat is utilized for spawning and rearing consistent with assessed habitat potential, in particular identified core areas	Available habitat is utilized for spawning and rearing consistent with assessed habitat potential.	Available habitat is fully utilized for spawning and rearing consistent with assessed habitat potential.
Life-history diversity – age, sex, juvenile life history, and migration and spawning timing adults and juveniles	Increasing variance in juvenile and adult traits over time	Increasing variance in juvenile and adult traits over time	Life history traits stabilized over time

[a] VSP metrics for all recovery phases will be updated through multiple generations of monitoring.

[b] Transition to Local Adaptation phase will occur at the end of the eight-year colonization experiment.

Table 4-2. VSP Attributes and Indicators

VSP Attribute	VSP Indicator	Relationship to Plan	Variables Monitored
Abundance	Natural-origin annual run to river	A key indicator of increased productivity of Nisqually Chinook. Indicator of response to increased spawner abundance, improved freshwater, delta, and marine habitat, and hatchery management actions.	Annual terminal run reconstruction estimates of natural-origin adults entering Nisqually River from fisheries and escapement variables
	Natural-origin adult recruits	Indicator of long-term trends in adult abundance and effectiveness of preterminal harvest rate constraints.	Estimates of adult equivalent recruitment (number of adults that would return to river absent preterminal harvest)
	Juvenile outmigrants	Indicator of response to increased spawner abundance, improved freshwater habitat, and age or life stage at migration attributable to hatchery management actions.	Abundance, age, and life-stage composition of outmigrant population over time across the entire juvenile migration period
	Natural-origin spawning escapement	Key indicator of increased productivity of Nisqually Chinook and effectiveness in meeting annual management targets (including harvest) for natural-origin spawning	Annual estimates of natural-origin and hatchery-origin spawners for all natural population components identified in plan
Productivity	Freshwater productivity (outmigrants per spawner)	Indicator of effectiveness of a) habitat efforts in freshwater to increase natural productivity and b) fitness effects attributable to hatchery management actions. Will be used to assess evidence for density dependence and fitness effects attributable to management actions.	Spawner escapement estimates, composition, and outmigrant abundance
	Marine survival (outmigrant to adult recruit back to river)	Indicator of a) habitat efforts in Nisqually delta and Puget Sound to increase natural productivity, b) fitness effects attributable to hatchery management actions and c) effectiveness of pre terminal harvest rate constraints.	Outmigrant abundance estimates (at outmigrant trap) and estimates of adult recruits back to river
	Life cycle productivity (adult run to river per spawner)	Indicator of potential of population to achieve recovery goals and effectiveness of management actions across entire life cycle.	Annual basin-wide estimates of natural natural-origin and hatchery-origin spawners and adult natural-origin return to river by brood year.
Spatial Distribution	Distribution of natural-origin spawners and juveniles relative to spawning and rearing habitat	Effectiveness of colonization and improved habitat—use of vacant or sparsely populated spawning and rearing habitat and newly restored habitat	Adult counts at Centralia Diversion Dam, spawning ground surveys in mainstem and tributaries upstream and downstream of Centralia Diversion Dam. Juvenile distribution and residence time in Nisqually delta

VSP Attribute	VSP Indicator	Relationship to Plan	Variables Monitored
Life-History Diversity	Migration and spawn timing, age at spawning, age and life stage at outmigration, body size and timing of outmigration, juvenile habitat rearing choice	Indicates to what extent increased influence of the natural habitat will affect diversity in observable attributes.	Multiple methods

Proposed Nisqually Chinook Implementation Plan

The primary goal of the Nisqually Chinook plan is the recovery of the population. The purpose of the hatchery program is to contribute to harvest (treaty and nontreaty) in a manner consistent with the long-term goal to recover the population.

The following sections summarize key aspects of the plan by recovery phase. Each section begins with a general overview of the working hypothesis underlying the phase, followed by the phase goals and objectives. The action plan for the phase is described and harvest, hatchery and escapement management actions described. Finally each phase concludes with an overview of monitoring activities specific to the phase. Additional monitoring details are described in Chapter 5, *Monitoring Tools and Objectives*.

Colonization Phase

The approach during the Colonization Phase is based on the hypothesis that habitat capacity in the Nisqually River, the delta, and the Puget Sound nearshore environment is under-utilized and thus can support greater abundances of juvenile and adult Chinook salmon than at recent levels of escapement and natural production. That is, there is under-utilized capacity in these areas to produce more Nisqually Chinook. The historical population data summarized in Chapter 2, *Current Status of Natural Population*, support this assumption.

The co-managers will use the Colonization Phase to refine biologically based decision rules for hatchery, harvest and escapement management for the Local Adaptation recovery phase. Those rules will be designed to improve population performance in terms of VSP attributes over time as the Chinook salmon population adapt to the watershed and to move the population toward the Viable Population phase.

The Colonization phase will follow a fixed timetable and will terminate by 2024 after approximately two brood years of Chinook supplementation and intensive monitoring. The management of Nisqually Chinook will then move into the Local Adaptation Phase.

Goal

Repopulate vacant, under-utilized, and restored habitats to increase natural production, abundance, and diversity of the population.

Objectives

Rebuild natural production to a level that meets abundance and productivity targets necessary to move management to the Local Adaptation Phase through the supplementation of natural spawning with hatchery-origin adults (i.e., trucking of hatchery adults and hatchery-origin adults naturally straying to spawning areas) by focusing on the following objectives:

1. Achieve an aggregate natural spawning escapement of hatchery- and natural-origin fish that exceeds 3,500 spawners. This escapement level is set to improve natural production to meet or exceed the lower end of the Local Adaptation biological targets for juvenile and adult abundance. The 3,500 adult objective corresponds to the highest level of outmigrants observed (2008 brood year and 2009 outmigrants [Figure 2-7]). This will be achieved through truck-and-haul techniques with hatchery-origin adults collected from the Clear Creek and Kalama Creek hatcheries. The aggregate natural

spawning escapement will be reviewed annually and may be updated if distribution of supplemented adults or juvenile production suggests a different escapement objective.

2. Monitor the population and evaluate management actions to:
   a. improve our understanding of freshwater habitat potential from adult spawning to juvenile outmigration,
   b. improve our understanding of fish use, resource constraints, and ecological interactions of juvenile Chinook throughout the river and delta to better understand relationship between freshwater production and survival to adult, and
   c. use these monitoring results to refine biological targets and management actions for the Local Adaptation phase
3. Continue the development of management tools for:
   a. preseason forecasting and in-season updates, and
   b. protocols for in-season updates to better forecast and manage preterminal and terminal area fisheries.
4. Explore new fishing techniques, gears and harvest management strategies to more effectively harvest hatchery-origin adults (more detail below).
   a. Implement co-manager proposal for testing commercial selective gear in treaty fishery

Action Plan

The approach in the Colonization Phase is to increase the total number of naturally spawning Chinook salmon (hatchery- and natural-origin) through adult supplementation to produce a greater abundance of juvenile outmigrants and natural-origin adult recruits back to the river. The transition from Colonization to Local Adaptation will follow a fixed timetable (Table 4-3). Monitoring the response of the Chinook population to aggressive supplementation through the duration of the Colonization Phase will be used to inform management actions including harvest rates, hatchery production and natural spawning escapement to achieve the goals of the Local Adaptation phase. In the Local Adaptation phase, the number of natural-origin adults entering the river needs to exceed 2,200 Chinook to support management actions for natural spawning and hatchery broodstock integration described in the next section for Local Adaptation. A terminal run is projected to achieve a lower end escapement objective of 1,500 natural spawners. Monitoring results during the Colonization phase will be used to review and potentially replace the population characteristics identified for the Local Adaptation phase.

Check-In Timeline and Adaptive Management

The Colonization phase will follow an 8-year timeline (Table 4-3) before a transition to Local Adaptation is made for the 2025 management season. During this period annual project reviews will occur to provide preliminary assessments of VSP attribute indicators described in Table 4-2, refine monitoring activities described in Chapter 5, *Monitoring Tools and Objectives*, and set actions and associated management targets for the upcoming year. Two formal check-ins to review progress are scheduled, the first in spring of 2022 and the second in spring of 2025 following the 2024 management season and at the end of the 8-year timeline.

The check-ins will be used to report on progress, update anticipated population characteristics for local adaptation (Table 4-1), and adjust program strategies. The check-ins will evaluate the relationship between total spawner abundance and juvenile outmigrants to assess freshwater productivity and abundance for indications of density-dependence. Indicators of density-dependence would suggest an upper capacity limit to freshwater production. Data collected to date indicate a linear relationship between spawner abundance and juvenile migrants (Figure 2-7). Evidence for a density-dependent relationship would show a declining productivity and upper limit to juvenile migrant abundance. In other words, a change in the linear relationship to an asymptotic relationship with an upper abundance. Other indicators of density-dependence could include greater variation in emigration timing (winter fry, spring parr, and summer fingerlings) and reduced mean size or condition of juvenile migrants.

- **Check-in #1 (2022):** After five years of adult supplementation (2017–2021) and outmigrant monitoring at the WDFW-operated screw trap (2018–2022), the relationship between total spawner abundance and juvenile outmigrants will be assessed for indications of a density-dependent relationship. Data collected to date indicates a linear relationship between spawner abundance and juvenile migrants (Figure 2). Evidence for a density dependent relationship would include an upper limit to juvenile migrant abundance, and a change in the nature of that relationship from linear to asymptotic. Other indicators of density-dependence would include greater variation in emigration timing and reduced mean size or condition of juvenile migrants. After five years of juvenile monitoring, the capacity parameter in a Beverton-Holt, Ricker, or hockey-stick stock-recruitment model will be estimated. There are two potential outcomes:

    - **Outcome 1:** Data indicate a better fit to a density independent (linear regression) model than a density-dependent stock-recruit. Should the spawner-juvenile recruit relationship indicate a density-independent relationship (linear), adult supplementation will continue until 2024. Managers will try to explore the upper bounds of the system capacity during this time.

    - **Outcome 2:** Data indicate a better fit to a density dependent stock-recruit model than a density-independent, linear model. If this is the case, adult supplementation would be discontinued and estimates of past juvenile to adult survival rates for the population will be applied to the juvenile abundance estimates to provide an estimate of adult recruits expected in years 2021 to 2025. Until adult returns are complete, these natural-origin adult recruit estimates can be used in a life cycle modeling approach to develop a hatchery actions (broodstock management; number, size, location of release) that achieve PNI targets consistent with local adaptation. The life cycle model approach would use the best available information on smolt to adult return rates in the Nisqually River and elsewhere in Puget Sound. Under this outcome, the program will enter the local adaptation phase.

- **Check-in #2 (Spring of 2025):** This is the final check-in the Colonization phase.

    - **Outcome 1**: The adult-to-juvenile stock-recruit relationship would be repeated as described in Check-in #1 above. However, the maximum number of years that the adult supplementation would be implemented is 8 years. If there is still no evidence for density dependent capacity limits after 8 years of supplementation, escapement targets for the Local Adaptation phase would be set based on the best available science.

    - **Outcome 2**: In 2024, age-4 natural-origin adult returns produced from the initial 2017–2021 adult supplementation phase will be complete. At this point, natural-origin recruits from 5 years of adult supplementation reflect the capacity of the Nisqually River basin, estuary, and Puget Sound nearshore environment to support naturally reproducing Chinook salmon. Although monitoring will continue, the HSRG framework indicated in this plan and the accompanying emphasis on broodstock management, including PNI objectives, will be used as the basis for hatchery production, broodstock management, and harvest management during the Local Adaptation phase.

Table 4-1. Timeline for the Colonization Phase

Brood Year[a]	Plan Year							
	2017	2018	2019	2020	2021	2022[b]	2023	2024[b]
2017	Start	Outmigrant	Age-2	Age-3	Age-4	Age 5		
2018			Outmigrant	Age-2	Age-3	Age-4	Age 5	
2019				Outmigrant	Age-2	Age-3	Age-4	Age 5
2020					Outmigrant	Age-2	Age-3	Age-4
2021						Outmigrant	Age-2	Age-3
2022							Outmigrant	Age 2

[a] Brood Years are planned years of adult supplementation described in text.

[b] Check-ins will occur in these years as described in the text, the last check-in will be in spring 2025 after the 2024 management season and before the 2025 season.

Adult Supplementation Operations Plan

Hatchery Chinook from Clear Creek and Kalama Creek hatcheries will be collected from the hatchery adult return ponds, biologically sampled (length, scales, tissue sample for DNA analysis, and mark status), jaw tagged, and released into the Nisqually mainstem upstream of the hatcheries at the Centralia City Light Yelm Hydro project Powerhouse (Centralia Powerhouse) boat ramp, and upstream of the Centralia Diversion Dam (Figure 4-1). Release sites were chosen because of transport time and the number of Chinook to be released. The upper site at Centralia Diversion Dam was chosen to allow adults to freely migrate to spawning locations in the upper Nisqually River and Mashel River. Release locations may be modified through the adaptive management process if transported Chinook are not distributing to spawning areas.

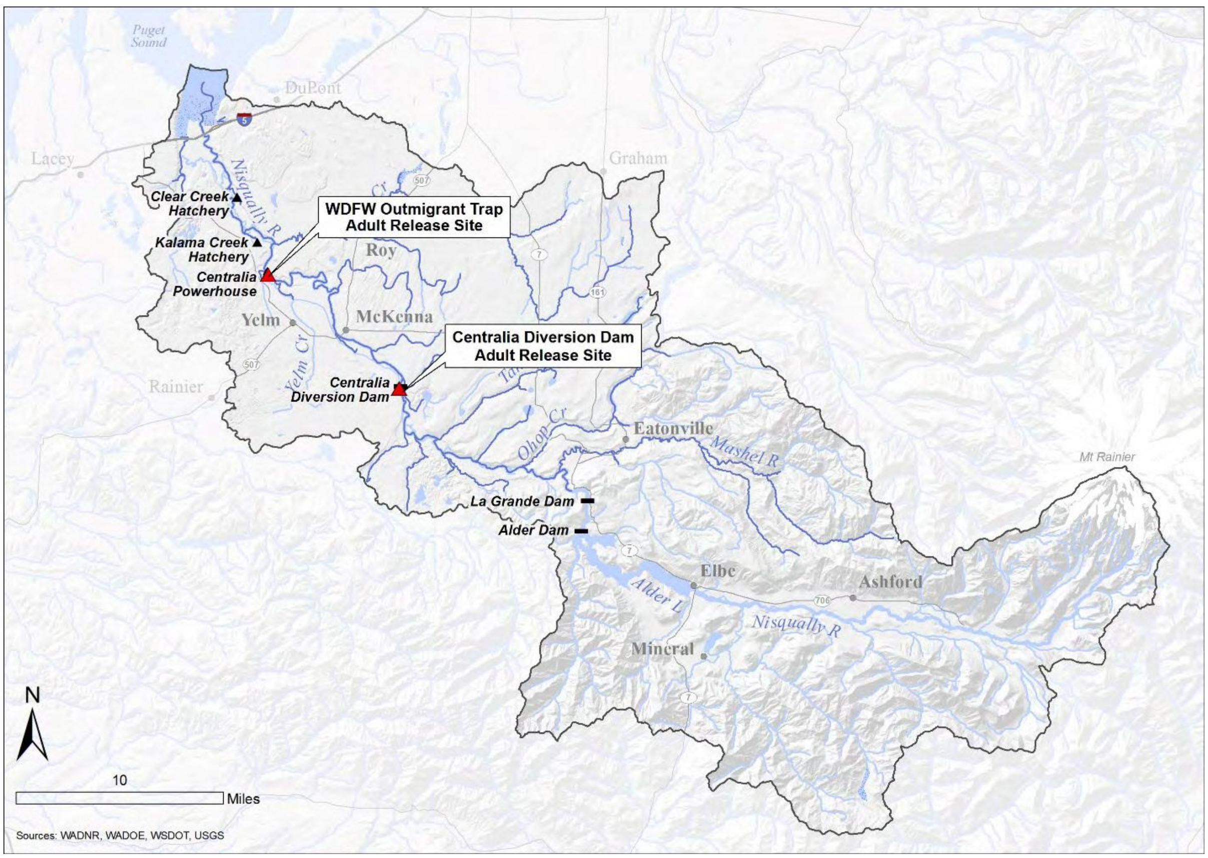
Adults with a coded-wire tag will not be transported and instead processed to remove the tag to collect as many coded-wire tag samples in the hatchery as possible to ensure tag recoveries sufficient for management purposes.

Transported adults will be equal numbers of males and females; the male portion will include 10% jacks (age 2). Adults that exhibit poor condition and deemed not viable for transport will not be transported.

The truck-and-haul operation will span the temporal extent of the annual adult return period, commencing during the first week adults enter the hatchery ponds and continuing until adults in the ponds appear to be no longer viable. A weekly schedule has been developed to avoid spawning days at the hatcheries and maximize the number of trucked fish. The objective is to truck and release up to 470 Chinook per week. Early in the season and near the end of the season when fewer adults are entering the pond a smaller truck will be used to transport adults to allow for smaller batches to be collected, sampled, and trucked. The daily objective of the plan are described below.

- **Monday:** Process, transport, and release approximately 70 Chinook at the Centralia Diversion Dam (RM 26.2). It is anticipated that the fish entering the adult return ponds over the weekend will provide adequate abundance to fill the Tribe's smaller transport trucks: 60 to 70 Chinook.
- **Tuesday:** Process approximately 200 Chinook for loading and transport in the larger WDFW trucks on Wednesday. No Chinook will be transported on Tuesday.
- **Wednesday:** Transport and release approximately 200 Chinook at the Centralia Diversion Dam at RM 26.2.
- **Thursday:** Process approximately 200 Chinook for loading and transport in the larger WDFW trucks on Friday. No Chinook will be transported on Thursday.
- **Friday:** Transport and release approximately 200 Chinook at the Centralia Powerhouse at RM 12.8.

Figure 4-1. Locations of Adult Hatchery Chinook Releases



Other Elements

The following activities will be implemented during the Colonization phase to prepare for the transition to the Local Adaptation phase and to support monitoring programs.

- Continue development of an operations plan for the integrated and stepping-stone hatchery programs based on the most current science, broodstock collection plan and spawning operations, and renovations to hatchery facilities.
- Install an adult trap in the Centralia Diversion Dam Fish Ladder (CDDFL). Designs are currently being developed and the current plan is to have the trap operational for the 2018 season. The trap will play a pivotal role for monitoring and evaluation during the Colonization phase and for broodstock collection and pHOS reduction in the Local Adaption phase.

Harvest Management

The harvest management objective during Colonization is to not exceed a 47% total exploitation rate cumulative through all fisheries for natural-origin Nisqually Chinook. The 47% exploitation rate management objective reflects the most recent incremental reductions identified for Nisqually River natural-origin Chinook in the Harvest Management Component of the *Comprehensive Management Plan for Puget Sound Chinook* (Puget Sound Indian Tribes and Washington Department of Fish and Wildlife 2010). Fisheries were successfully managed to not exceed a total exploitation rate of 65% in 2010 and 2011; 56% in 2012 and 2013; 52% in 2014 and 2015; 50% in 2016; and 47% in 2017. The reductions in the total exploitation rate bared solely by the treaty and sport terminal fisheries have helped stabilize escapements following a decline in natural-origin abundance and ensured adequate number of Chinook spawning naturally.

During preseason planning, the FRAM projection of the exploitation rate for unmarked Nisqually Chinook stock will inform compliance with the harvest management objective. Preterminal and terminal fishery rates will be set during the North of Falcon process for preseason to comply with the 47% total exploitation rate. The Tribe's preseason harvest goals for Chinook in the terminal area (Nisqually River) include a treaty harvest rate target that will not exceed the total exploitation rate of 47% and a floor harvest rate of 20%. Nontreaty sport harvest has been limited to adipose fin-clipped Chinook since 2005; the harvest rate on unmarked Chinook, from incidental mortality caused during catch and release, has averaged 4% since the implementing mark-selective fisheries. Preterminal fisheries will make necessary adjustments to not exceed the exploitation rate.

The co-managers will continue to manage the terminal fishery to meet preseason expectations and reduce the chances of exceeding the harvest management objectives while providing for meaningful treaty right fishery and nontreaty sport fishery.

Selective Fishery

The Nisqually Indian Tribe, with the full agreement of the WDFW, will be conducting an investigation into gear types and opportunities to selectively harvest hatchery-origin Chinook in the Tribe's traditional commercial fisheries during the Colonization phase. The Tribe will undertake this investigation utilizing up to an additional 2% ER through a combination of staff and fisher implemented actions consistent with the recovery objectives for the Colonization phase. We will monitor the instantaneous mortality associated with each gear type, the relative success of the gear types, and the response of the fishers to the gear. The Tribe will report the results of the annual investigation of selective gear types during our annual adaptive management review.

The investigation will use up to an additional 2% ER during a nonpink year in 2018 and a pink year in 2019. We will not experiment in 2020. We will then select our preferred gear types for additional testing utilizing up to an additional 2% ER in 2021 and 2022. Unless agreed to by the co-managers and NOAA Fisheries, the experimental phase of this effort will sunset after the 2022 season. Based on the results of our previous work and with input from WDFW and NOAA Fisheries, the Tribe will determine which gear type(s) to integrate into our commercial fishery within the 47% ER in 2023 consistent with the recovery objectives for that season. Our desire is to identify and implement selective opportunities acceptable to the tribal community with an agreed to understanding of the release mortality by the time we reach the Local Adaptation phase and an increased need to manage for escapement composition.

The co-managers will work together to continue to provide meaningful sport fishing opportunities in the Nisqually River.

McAllister Off-Site Fishery

The McAllister extreme terminal fishery will target the returning adults from releases of sub-yearling marked Chinook from McAllister springs. The treaty fishery will be open in the extreme terminal area from the mouth of McAllister Creek up to the trap at the outlet of the springs. This fishery will not be open the same days as the Nisqually River treaty fishery to eliminate confusion when sampling. The McAllister treaty fishery will utilize a combination of gear types and will harvest as many returns as possible because all broodstock production needs will come from Clear Creek Hatchery in the Nisqually River. The fishery will be sampled at a minimum of 20% of the total catch. The distribution of McAllister off-site release adults will be monitored in preterminal and extreme terminal area fisheries, at both Clear Creek and Kalama Creek hatchery racks, and on the spawning grounds.

Hatchery Management

Planned hatchery releases during the Colonization phase are presented in Table 4-4 by release location. During this phase, hatchery broodstock will continue to use hatchery-origin returns; natural-origin adults will not be incorporated for use as broodstock. Relocating 1.0 million fish of the total annual hatchery subyearling production of 4.0 million fish to an out-of-river release location at McAllister Springs is expected to allow high harvest rates on returning hatchery-origin fish by the treaty net fishery in McAllister Creek with a low impact on natural-origin escapement in the Nisqually River. Furthermore, moving a portion of the production to McAllister Creek may be an important strategy to reduce contribution of pHOS in the Local Adaptation phase.

All hatchery releases will be adipose-fin-clipped except for a portion of the Clear Creek release that will instead not be adipose fin clipped but will be code-wire-tagged to monitor mark-selective fisheries. A portion of the fish released at each release location will be coded-wire tagged with a tag code unique to each release site to monitor survival, contributions to fisheries, and adult spawning distribution.

Table 4-2. Planned Annual Chinook Release by Location

Release Location	Annual Release	Life Stage
Clear Creek	2.4 million	Sub-yearling (fingerling)
Kalama Creek	600,000	Sub-yearling (fingerling)
McAllister Springs	1.0 million	Sub-yearling (fingerling)

Escapement Management

As described previously, during the Colonization Phase the objective for natural spawning is to exceed 3,500 natural spawners throughout the watershed. Natural spawning will include adults from three sources:

- Natural-origin returns escaping fisheries
- Hatchery-origin volunteers to natural spawning (strays)
- Hatchery-origin fish trucked and hauled from Kalama Creek and Clear Cleek hatcheries

During the Colonization Phase, the escapement objective will be met through transport and release of hatchery-origin fish from the two hatchery facilities. Releases will occur at two mainstem locations to allow free migration of adults to spawning areas in the mainstem and tributaries (Figure 4-1). An aggregate natural spawning escapement of natural-origin adults and hatchery-origin volunteers (i.e., strays) may comprise up to 1,500 spawners in a year. Therefore, truck-and-haul of adults from the hatcheries will need to augment natural spawning areas with at least 2,000 fish each year. Assuming trucking capacity described previously to haul approximately 500 adults per week, 4 to 5 weeks of transport will be required.

Monitoring

The focus of the monitoring program during the Colonization phase is to evaluate Nisqually River freshwater and delta potential and use for natural production, to provide the information necessary to evaluate VSP attribute indicators and biological targets, and to evaluate plan assumptions for the Local Adaptation phase (e.g., distribution of returning adults from the McAllister Springs release).

Monitoring actions during the Colonization phase will focus on collecting information to evaluate the plan premise that natural production of Chinook is limited by low natural spawning. In other words, escapements of 3,500 adults will test the limits to freshwater and delta abundance from habitat capacity.

Monitoring methods will be refined during the Colonization phase in anticipation of transitioning to the Local Adaptation phase. Operational guidance of the adult trap in the Centralia Diversion Dam Fish Ladder will be developed during this phase. The trap will be used in the Colonization phase to enumerate escapement to the upper basin and collect tissues samples for the genetic parentage study. The trap will be used in the Local Adaptation phase to collect natural-origin broodstock and remove hatchery-origin from natural spawning.

The Colonization phase will depend on the successful transportation of hatchery-origin Chinook throughout the watershed to maximize the number of adults on the spawning grounds. Intensive monitoring will allow for the evaluation of the success of these fish by gaining a better understanding of: the movement and distribution of trucked hatchery adults; the spawning success of trucked hatchery adults; and the abundance, age structure, and genetic composition relative to natural-origin Chinook and naturally straying hatchery fish.

An important monitoring element during the Colonization phase will be a genetic parentage study to evaluate relative contribution of hatchery-origin and natural-origin spawners to natural production (juvenile and adult). The details of the genetic parentage study are described in Chapter 5, *Monitoring Tools and Objectives*. The parentage study is a core monitoring element during the Colonization phase.

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The monitoring activities are designed to meet the goals of understanding the movement and distribution of trucked hatchery Chinook, monitoring the spawning success of trucked hatchery Chinook, collecting abundance and biological data from natural-origin Chinook and hatchery-origin strays, assessing contribution from the McAllister release program, and gathering stock composition data to estimate spawning and return abundance using the change-in-ratio method. Spawning ground survey locations and methods are described in more detail in Chapter 5, *Monitoring Tools and Objectives*. All trucked Chinook will be released with a jaw tag on the right side of the jaw. This will allow surveyors and those monitoring Chinook passage at the Centralia Diversion Dam (camera in 2017 and adult trap in future years) to distinguish trucked adults from hatchery-origin strays and natural-origin spawners. To evaluate spawning success of trucked fish, egg retention and distribution of carcasses will be compared for trucked hatchery-origin, natural-origin, and straying hatchery-origin Chinook salmon. Egg retention will be estimated by comparing the residuals of egg mass in the body cavity to fish length of individual carcasses. Release locations may be modified through the adaptive management process described in Chapter 3, *Phased Recovery Approach,* if data indicate transported Chinook are not distributing to spawning areas.

Hatchery adult ponds will be monitored for jaw-tagged Chinook to evaluate the number that return back to the hatchery after trucking. These will be subtracted from the number released to get the total number of Chinook supplemented to the river.

The total number of fish transported and released will be added to the change-in-ratio based escapement estimate described in Chapter 5, *Monitoring Tools and Objectives,* to estimate total watershed-wide spawning abundance.

McAllister Creek will be surveyed weekly for adults to determine distribution of returning hatchery-origin from the McAllister Springs release and to improve the accuracy of estimates of survival rates for this release. Coded-wire tag recoveries from spawners in the mainstem Nisqually will be assessed for origin to determine the stray rate of McAllister releases to the Nisqually.

Local Adaptation Phase

The transition to local adaptation will occur after no more than 8 years of colonization. Population characteristics described in Table 4-1[1] represent the desired conditions for initiating management actions for local adaptation such as removing hatchery origin Chinook from the river and integrating a portion of the hatchery program. However, even if population productivity and abundance conditions described in Table 4-1 are not achieved the transition to local adaptation will still occur and hatchery program size, integrated broodstock, and natural spawning escapement described in this plan will need to be revised to ensure successful management in local adaptation. Hatchery program size may need to be reduced to meet objectives for pHOS and PNI necessary to achieve the goals of local adaptation.

In local adaptation harvest management will shift from a exploitation rate objective to a combined escapement based and exploitation rate management regime, to be protective of conservation objectives at lower run sizes and to take advantage of larger run sizes.

[1] Population characteristics described in Table 4-1 will be evaluated and possibly revised at the two check-ins described during the Colonization phase. The evaluation will use monitoring information collected during colonization.

Goal

Establish a thriving, locally adapted natural population of Chinook salmon in the Nisqually River by reducing hatchery influence to promote rebuilding and improvements in fitness in natural origin Chinook while maintaining hatchery production to support treaty and nontreaty fisheries.

Objectives

The Local Adaptation phase will shift priorities and decision rules based on the information learned from the Colonization phase, which will affect harvest, hatchery, and escapement management.

The management priority during Local Adaptation is to emphasize conservation and growth of natural production gains achieved during the Colonization phase. The management of harvest rates, hatchery size, and broodstock composition will be adjusted as needed to meet the Local Adaptation goal. This includes managing for an escapement range of natural-origin adults that optimizes natural production, reducing the contribution of hatchery-origin adults to natural spawning, using natural-origin adults in the hatchery broodstock, and realizing improvements in freshwater, delta, and nearshore marine habitat. Objectives for habitat improvement are described in Chapter 2, *Continuing Habitat Efforts and Watershed-Wide Issues.* Substantial progress has been made in the watershed and continuing efforts are expected to build on this progress.

The goal of reducing hatchery influence on the population will be achieved by focusing on the following objectives. These targets and the associated strategy will be adjusted based on the results of the colonization phase experiment and as new science becomes available.

1. Manage hatchery broodstock and escapement composition to achieve a 4-year running average management objective for PNI of 0.50 or greater and to ensure progress toward a PNI of 0.67. PNI calculations will use pNOB values for the integrated component at Kalama Creek and pHOS will be based on hatchery-origin spawners from all three release groups (Kalama Creek, Clear Creek and McAllister Springs). PNI will be calculated using the MP-PNI calculator developed by NOAA F.

2. Manage watershed-wide escapement composition to not exceed an annual pHOS of 30% and escapement composition upstream of the Centralia Diversion Dam to not exceed an annual pHOS of 10%.

3. Manage hatchery broodstock for the integrated program at Kalama Creek Hatchery to initially comprise 25% natural-origin Chinook and increase to 100% with higher natural-origin abundance. This would represent between 110 and 425 natural-origin broodstock although this number could change as the program is adjusted to meet the Local Adaptation goal.

4. Manage hatchery broodstock for the stepping-stone program at the Clear Creek Hatchery and the McAllister Springs release to comprise only returns of integrated adults to the Kalama Creek Hatchery.

Annual management objectives for pHOS, pNOB, and resulting PNI will be developed and reported during preseason planning for the upcoming year. Annual management objectives will be developed consistent with recovery status and be based on preseason run size forecasts of natural-origin Chinook to the Nisqually River.

During the Annual Program Review each spring preseason objectives developed during the previous program review will be evaluated against actual results for the year. A 4-year running average of pHOS and PNI will be used to evaluate long-term recovery progress.

Action Plan

The Local Adaptation phase will not follow a set timeline. Population characteristics described in Table 4-1 will define progress and the transition to the Viable Population phase. Monitoring will be an important element to update status and trends of the natural population using indicators of VSP described in Table 4-2. The adaptive management process described in Chapter 3, *Phased Recovery Approach,* will be used to adjust strategies and set annual management actions.

Specific measures to reduce the number of hatchery-origin adults spawning in nature include the removal of marked (adipose-fin-clipped and/or coded-wire-tagged) adults at the Centralia Diversion Dam adult trap, the release of 1.0 million Chinook from McAllister Springs and an associated directed fishery, and implementing mark-selective fishing techniques in the treaty terminal fisheries. If these measures are not sufficient to meet the pHOS objectives for Local Adaptation then the Tribe will reduce the Clear Creek Hatchery release.

In addition to these measures to reduce the number of hatchery-origin adults spawning in nature, pHOS will be reduced by managing preterminal and terminal harvest on natural-origin adults to meet or exceed the escapement range for natural spawning described in Table 4-1[2]. The escapement range will be met using an annually adjusted exploitation rate not to exceed 47%. Meeting the escapement target may require reducing the integrated Kalama Creek Hatchery release to maintain the pNOB target in years of low abundance of natural-origin adults. Reductions in the integrated program may have a consequence on future program size of the stepping-stone program if the number of integrated hatchery returns is insufficient to meet the stepping-stone broodstock needs.

Plan assumptions during local adaptation are described in Table 4-5. The assumed proportion of hatchery-origin Chinook that stray to the spawning grounds is based on recent year observations. Currently, it is estimated that 6% of adult Chinook returning to the Clear Creek and Kalama Creek hatcheries stray to natural spawning areas. The number of hatchery-origin Chinook escaping fisheries to spawn is based on a Nisqually River Chinook release of 3.0 million Chinook and a 1.0 million Chinook release from McAllister Springs with an associated directed fishery. The plan assumes 90% of the hatchery-origin adults attempting to migrate to the upper watershed will be removed at the adult trap in the Centralia Diversion Dam fish ladder. The plan assumes that hatchery-origin Chinook stray at equal proportions above and below the Centralia Diversion Dam. This assumption will be evaluated during the Colonization phase.

Under the assumptions shown in Table 4-5 with a run size to the Nisqually River of 2,300 adults at the initial transition (Early) to Local Adaptation phase, results from the MP-PNI model indicate an average PNI exceeding 0.50.

Under the assumptions shown in Table 4-5 with a run size to the Nisqually River of 5,400 adults at the end of the Local Adaptation phase (Late) and the transition to Viable Population Phase, results from the MP-PNI model indicate an average PNI exceeding 0.67. A run size of 5,400 adults represents a spawning escapement of approximately 3,400, after terminal harvest and

[2] Population characteristics described in Table 4-1 will be evaluated and possibly revised at the two check-ins described during the Colonization phase. The evaluation will use monitoring information collected during colonization.

broodstock removal, which is the high productivity target abundance in the 2006 Puget Sound Salmon Recovery Plan.

Table 4-3. Local Adaptation MP-PNI Modeling Assumptions and Results

		Local Adaptation Phase	
		Early	Late
Population Characteristics	Productivity - Spawner to Adult	1.5	3.0
	Abundance - Natural-Origin Run to the River	2,300	5,400
	Abundance - Natural-Origin Spawning Escapement (after terminal harvest and broodstock removal)	1,527	3,411
Terminal Area Fisheries Management	Treaty Net Fishery Harvest Rate	25%	25%
	Non Treaty Sport Impact (non-landed mortality)	4%	4%
	Combined	29%	29%
Hatchery Broodstock Management Integrated Program	pNOB	25%	100%
	# Natural-origin Removed for Broodstock	106	423
Escapement Management and Resulting Management Targets for pHOS	Percent Hatchery-origin Straying to Natural Spawning	6%	6%
	Number Hatchery-origin Spawning Below Centralia Diversion Dam	508	508
	Percent Hatchery Removed at Centralia Diversion Dam	90%	90%
	Number Hatchery-origin Spawning Upstream of Diversion Dam	51	51
	pHOS below Centralia Diversion Dam	33%	17%
	pHOS Above Centralia Diversion Dam	10%	5%
	Combined pHOS Basin-wide	27%	14%
MP-PNI Results	Calculated Equilibrium PNI using MP-PNI formula with Integrated and Stepping-stone Hatchery	0.59	0.86

It is possible that the population may get "stuck" in local adaptation if PNI remains at or near 0.50, in which case the natural environment is counter-balanced by the hatchery environment and adaptation to the natural environment stalls. In this scenario, multiple generations with PNI higher than 0.50 are needed to move adaptation to the natural environment and improve fitness and productivity (recruits per spawner). Increasing PNI beyond 0.50 depends, at least in part, on greater natural productivity to increase abundance of natural origin to reduce pHOS and allow management actions to increase pNOB of the integrated component. Therefore, it may be necessary to manage for PNI greater than 0.67 before realizing gains in natural productivity. In practice, this would mean that the size of the aggregate hatchery programs during local adaptation would be limited by the total abundance of natural-origin adult returns.

During the Local Adaptation phase annual management decisions will consider the 4 year running average of PNI with the objective to continually improve the PNI running average. That means small deviations in PNI from year to year are acceptable as long as the running average is continuing to improve. In practice, the 4 year running average PNI will be calculated each spring during the annual project review based on previous year data. The next year forecast PNI will be calculated and added to the 4 year running average. If the forecast running average is declining then additional management actions will be developed to increase the next year PNI to produce an upward trend in the running average. Additional actions may include reducing the hatchery program size and implementing additional selective fisheries to remove more hatchery origin returns.

Harvest Management

The harvest management approach, including management objectives, will be reviewed consistent with the data-driven assessment of the Nisqually Chinook salmon population productivity and capacity during the Colonization phase, described above. Adjustments will be made to harvest impacts to protect the natural-origin Chinook run to the river and spawning escapement consistent with the productivity and capacity of the natural population. The intent is to ensure that harvest management is consistent with annual management objectives set for the Local Adaptation phase such as escapement abundance and composition, hatchery broodstock pNOB, and resulting PNI.

Harvest management objectives during the Local Adaptation phase will shift to an escapement-exploitation based approach for natural-origin Chinook with a total exploitation rate in years of high abundance to not exceed 47%. For planning purposes a lower end escapement goal is set at 1,500 natural-origin Chinook. However, more refined numeric escapement objectives for local adaptation will be developed based on the data assessment during the colonization experiment. The purpose of the escapement objectives coupled with a sliding exploitation rate is to optimize natural production and to maintain the Nisqually Indian Tribe treaty fishery. A sliding scale exploitation rate not to exceed 47% will provide higher escapements in years of high abundance and opportunities to evaluate natural production at higher escapement levels.

Harvest management decisions will be reviewed and adjusted to ensure natural abundance does not revert back to the previous recovery phase. Preterminal fisheries will adjust accordingly during the preseason planning process to meet management objectives for the natural-origin run to the Nisqually River. Management objectives for the terminal fishery will be to provide a meaningful treaty fishery in the Nisqually River while protecting natural production. A meaningful Nisqually Indian Tribe fishery is defined as a 25% harvest rate on natural-origin returns. Alternative fishing gear and area management (McAllister off-site fishery, see description under Colonization) to target hatchery-origin adults will be important to achieving the Tribe's Chinook harvest goals.

In the event that the abundance of natural-origin Nisqually Chinook in preterminal fisheries and forecast abundance back to the river are below the escapement objective for the population, preterminal and terminal fisheries will be adjusted to the maximum extent possible. However, reducing harvest on natural-origin adults will have a consequence on the number of hatchery-origin adults returning to the river and escaping to spawn in nature, thereby impacting management objectives for pHOS and PNI.

Hatchery Management

Recognizing that harvest is an important goal for treaty and nontreaty fisheries, the plan initially will maintain the hatchery production of 4.0 million fish (Table 4-4) while implementing measures to meet conservation goals. However, the hatchery program size will be carefully reviewed with new information collected during Colonization, and reductions in program size may be necessary to achieve annual management targets for pHOS and pNOB.

The isolated hatchery program at Kalama Creek will be converted to an integrated program to continue to provide Chinook for treaty and nontreaty harvest while reducing hatchery influence. Integration of the Kalama Creek program will occur in phases. Initially, pNOB will be set at 25% (approximately 110 Chinook) independent of projected natural spawning escapements that may exceed 1,500 Chinook. However, PNOB will be incrementally increased to 100% (approximately425 Chinook) in subsequent years when run sizes are higher and projected natural spawning escapements would exceed 1,500 Chinook. The decision rule for incremental increases in pNOB with higher projected escapements will be developed based on the spawner-recruit analysis conducted following the colonization experiment.

Consistent with the best available science and the MP-PNI model, and assumptions refined during the Colonization phase, the isolated hatchery program at Clear Creek will be converted to a stepping-stone program to continue to provide Chinook for treaty and nontreaty harvest while reducing hatchery influence. During the Local Adaptation phase, the broodstock for the stepping-stone hatchery program will be entirely from returns from the integrated Kalama Creek hatchery program. Therefore, the pNOB rule for the stepping-stone program is 0%.

The release at McAllister Springs, which consists of Chinook from the isolated hatchery program during Colonization, will consist entirely of returns from the Kalama Creek Hatchery integrated program during the Local Adaptation phase.

If the number of adults returning to the Kalama Creek Hatchery is unable to support broodstock needs for the two stepping-stone programs, then the Clear Creek and the McAllister Springs releases will be reduced. The formula for adjusting these releases will be developed in the future. Factors affecting this decision are survival of and harvest opportunities on the McAllister release and stray rates from this program. These factors may favor maintaining the Clear Creek over the McAllister release.

At full implementation of the integrated program at Kalama Creek (pNOB = 100%), Chinook will be exposed to the hatchery environment for no more than two successive generations (once at Kalama Creek and again at Clear Creek in the harvest component of the program), thereby further reducing the risk that the harvest program will diverge substantially from the natural-origin component of the Nisqually population that is becoming locally adapted.

Escapement Management

During the Local Adaptation phase, reducing hatchery influence on natural spawning becomes a priority. This will be achieved through removing hatchery-origin strays from natural spawning at the Centralia Diversion Dam, managing fisheries to protect gains made in natural-origin abundance during the Colonization phase, and developing methods to selectively harvest marked hatchery adults.

During local adaptation, escapement will be managed for a target range of natural-origin spawners. The escapement range will be developed using information collected during the Colonization phase.

Escapement management is closely tied to harvest management decision rules. Harvest and natural-origin removals for broodstock will be adjusted to achieve the targeted escapement range. Fisheries and broodstock collection will be adjusted to the extent possible to stay within the range.

Monitoring

Monitoring programs during Local Adaptation include activities to evaluate plan assumptions for productivity and abundance of the natural population, the number of hatchery-origin returns and their distribution, spatial structure and diversity of the naturally spawning population and juvenile production, and the operational criteria for the integrated and stepping-stone hatchery programs.

Monitoring programs during Local Adaptation will collect information to evaluate the plan premise that reducing hatchery influence on the natural population will improve fitness of the population. Monitoring programs will estimate natural-origin adult run size, spawning escapement, and natural production and habitat use of juveniles.

Several monitoring activities are specific to evaluating annual management targets. Monitoring will need to estimate the number of adults spawning upstream and downstream of the Centralia Diversion Dam, reproductive success, and the associated pHOS for these components.

Viable Population Phase

Goal

Maintain a productive, resilient, spatially and temporally diverse Nisqually River Chinook population that is taking full advantage of the available habitat.

Objectives

The primary objective during this phase will be to monitor the natural-origin population for trends in natural production and adjust harvest and hatchery management actions to continue to support a thriving natural-origin population.

Action Plan

The Viable Population Phase is achieved once conservation and harvest goals can be achieved and sustained over time. The biological targets for this phase (Table 4-1) represent a population is productive, fit and taking full advantage of a healthy watershed.

Annual management targets include a high PNI (greater than 0.67) consistent with a Tier 1 population. Abundance and productivity of the natural-origin population is expected to be high, which will allow greater flexibility in setting annual management targets. Escapement composition is expected to be dominated by natural-origin adults with higher abundance.

Harvest Management

Harvest management objectives during the Viable Population Phase will continue to be based on protecting natural-origin Chinook escapement. Successful transition to Viable Population status implies high productivity and abundance for the natural population, which will support a higher overall harvest rate than during Local Adaptation. Preterminal and terminal fisheries will adjust accordingly to meet management objectives for the natural-origin run to the Nisqually River. As described in the next section, the number of hatchery Chinook released would likely be lower and the stepping-stone program would have switched to an integrated program. Harvest management objectives will be revised to support an integration of hatchery broodstock to a level that on average exceeds a PNI of 0.67.

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Hatchery Management

The stepping stone hatchery program will be discontinued and replaced with a high-pNOB integrated program to supplement harvest. The specific size of the program will be determined through population and habitat monitoring, and will strike a balance between broodstock requirements, natural-origin escapement needs, and harvest goals.

Escapement Management

During the Viable Population phase, maintaining a low proportion of hatchery-origin Chinook proportion on the spawning grounds is a priority. This will be achieved through hatchery program reductions, removing hatchery-origin strays from natural spawning at the Centralia Diversion Dam, managing fisheries to protect gains in natural-origin abundance, and applying methods to selectively harvest marked hatchery adults.

Monitoring

Monitoring programs during Viable Population are needed to monitor status and trends of the natural population and provide information to make corrections to strategies with a changing climate and future pressures on population viability.

Chapter 5
Monitoring Tools and Objectives

This chapter describes the core monitoring programs that are fundamental to support implementation of the stock management plan and to evaluate progress. It also describes additional monitoring that could supplement the core programs pending additional funding.

An important objective of the monitoring programs is to apply the best possible methods with the resources available and consistently monitor the VSP attribute indicators identified in Table 4-1. The success of this plan will be tied to the effectiveness and speed of learning about the relative efficiency of different strategies and actions, and the ability to adapt to changing circumstances, including climate change. Making timely decisions and adjusting management actions based on new information and circumstances obtained through the monitoring program are essential to the success of the plan.

Plan implementation will be grounded in a scientific approach of hypothesis testing and informed decision making. The adaptive management process described in Chapter 3, *Phased Recovery Approach,* will evaluate VSP attribute indicators and the need for exercising contingencies or other adaptive responses to revise strategies and schedules for managing Nisqually Chinook, and define the end points at which goals are attained.

The monitoring programs described in the following sections are the best possible methods given the resources available and constraints of the Nisqually watershed. They are intended to inform the following factors, all of which are fundamental to the adaptive management process:

- Key assumptions (e.g., freshwater capacity) for which uncertainty and data gaps exist
- Status and trends analysis used to evaluate plan progress
- Achievement of annual management targets for harvest, hatchery, and escapement
- Assessment of biological targets that guide transition between phases

Table 5-1 describes the core and additional monitoring activities by monitoring variable for each of the five programs: adult catch and escapement monitoring, juvenile freshwater monitoring, juvenile Nisqually River delta monitoring, hatchery monitoring, habitat monitoring, and stock-recruitment analysis.

Table 5-1. Monitoring Programs

Monitoring Program	Monitoring Variables	Core Monitoring	Additional Monitoring
Adult Catch and Escapement Monitoring	Nisqually River Catch in Treaty and Sport fisheries	• Sampling of the treaty net fishery (sampling min 20%, typical 45%) for marks, CWT, age, and size and sex. Sampling estimates contribution of natural-origin fish to catch • In the absence of creel samples Catch Record Cards reporting of the sport catch of harvest marked and harvested unmarked Chinook and estimates impact of landed and incidental mortality of natural-origin • Total encounters estimated from years of CRC and creel study years	• Creel sampling of sport fishery and methods to estimate impact of landed and incidental mortality of natural-origin • Mark-selective fishery study commercial selective fishery and sport nonlanded mortality • Study net dropout rate in freshwater commercial fishery
	Nisqually Watershed-Wide Adult Escapement and Composition	• Escapement estimated from change-in-ratio method (Seber 1982) • Watershed-wide composition and distribution (hatchery- and natural-origin) based on: ○ Carcass sampling priority index reaches in the Mashel (RM 3.2 to RM 0) and Nisqually River (RM 26.2 to RM 21.9); these will be surveyed weekly ○ Supplemental nonindex reaches (Nisqually River RM 32.9 to RM 26.2 and RM 15.7 to RM 10.1); these will be surveyed biweekly.	• Historical escapement estimated from live and dead counts and expansion formula (Tweit 1986) and will be calculated to better understand bias in the historical abundance estimates. • Additional surveys may be conducted in the Mashel and Nisqually River as resources allow
	Adult Escapement and Composition Upstream of the Centralia Diversion Dam	• Abundance and composition from adult passed or excluded at the Centralia Diversion Dam adult trap (Colonization will include hatchery origin) • Composition estimated from carcass recoveries from priority index reach (surveyed weekly) in the Mashel (RM 3.2 to RM 0); supplemented with nonindex reach (Nisqually River RM 32.9 to RM 26.2) surveyed biweekly	• Radio tagging and tracking of adults (hatchery- and natural-origin) captured in lower river/delta to evaluate migration and spawning behavior through lower river and above Centralia Diversion Dam

Monitoring Program	Monitoring Variables	Core Monitoring	Additional Monitoring
	Adult Escapement and Composition Downstream of the Centralia Diversion Dam	• Abundance based on subtraction of CDDFL counts • Composition estimated from carcass recoveries from priority index reach (surveyed weekly) in the Nisqually River (RM 26.2 to 21.9); supplemented with nonindex reach (Nisqually River RM 15.7 to RM 10.1) surveyed biweekly	• Radio tagging and tracking of adults (hatchery- and natural-origin) captured in lower river/delta to evaluate migration and spawning behavior through lower river and above Centralia Diversion Dam • Additional surveys could be conducted to supplement carcass data below CDDFL
Juvenile Freshwater Monitoring	Freshwater Productivity, Capacity, and Juvenile Life History	• Operation outmigrant trap at RM 12.8 to estimate abundance, timing, life stage, and size of juvenile migrants • Productivity: # outmigrants per natural spawner • Capacity: # outmigrants by life stage • Life history: relative abundance of outmigrants by life stage	
Juvenile Nisqually River Delta Monitoring	Juvenile Life History Diversity (temporal and spatial), Delta Productivity and Capacity,	• Beach seining sites in all habitat zones (matching sites that have been monitored regularly in previous years), allows for understanding of spatial and temporal diversity, relative abundance, and long-term comparisons • Randomly selected beach seine sites in each habitat zone for density and capacity analyses	• Lampara net sampling of mudflats • Fyke net sampling of channels • Benthic, fallout and neuston sampling for prey availability monitoring • Bioenergetics, habitat connectivity, accessibility, and fish density across a wide range of natural and hatchery juvenile abundances • Monitoring habitat use, movement, and residence time of juveniles using passive integrated transponder (PIT) tags; • Otolith analyses for growth, residence time, and life history types surviving to adult return.

Monitoring Program	Monitoring Variables	Core Monitoring	Additional Monitoring
Hatchery Monitoring	Hatchery broodstock, in-hatchery survival, release, and post-release survival	• Number of adults and jack counts to hatcheries and McAllister Springs/Creek plus outlet creeks and McAllister Creek • Number of hatchery-origin adults used for broodstock • Number of natural-origin adults and jacks collected for broodstock • Survival rates (surviving to spawn) of natural-origin adults used for broodstock • Fecundity of hatchery- and natural-origin adults used for broodstock • Age composition (hatchery- and natural-origin) • Survival rates green egg to eyed egg • Survival rates eyed egg to ponding • Survival rates ponding to release • Number released, dates, size of fish, and number marked	
Habitat Monitoring	Habitat Project Implementation and Habitat Condition	• Track implementation of Chinook habitat action plan ○ Percentage of mainstem and primary tributaries protected ○ Acres of floodplain and estuary restored ○ Miles of tributary restored (e.g., engineered logjams, channel reconnection)	• Habitat status and trends monitoring to track impervious surface, riparian condition, temperature, flows, in-stream habitat diversity, sediment, etc.
Stock Recruitment Analysis	Natural-Origin Adult Abundance to River	• Terminal adult natural origin run calculated as the sum of the following: ○ In-river catch and nonlanded mortality (released fish) (sport based on catch record card, treaty based on fishery samples) ○ Natural-origin adults removed for broodstock (Local Adaptation) ○ Watershed-wide natural spawning escapement of natural-origin adults	• Sport catch may be estimated from creel survey data
	Survival rates from juvenile outmigrant to adult	• Survival rates based on outmigrant estimates and estimate of natural-origin adult recruits to river • Requires age data from unmarked (natural-origin) for recruit analysis; check this data	• Otolith microchemistry and microstructure for growth, residence time, and life history types surviving to adult return

Monitoring Program	Monitoring Variables	Core Monitoring	Additional Monitoring
	Spawner to adult brood year recruitment rates	• Recruitment rates calculated from the following: ○ Parent natural spawning abundance by origin ○ Terminal natural-origin run allocated to brood year; data from treaty fishery sampling used to estimate total age of adults in annual run (catch plus escapement) ○ Estimation of age 2 recruits/spawner	
Nisqually Chinook Genetics Assessment	Genetic Mark Recapture	• Estimate adult abundance using trans-generational genetic mark recapture (tGMR) • Estimate effective breeders by origin • Estimate relative contribution to juvenile production for the three adult types in the escapement (natural origin, hatchery origin volunteers, and hatchery origin truck and hauled) • Conduct a genetic based brood year reconstruction to evaluate relative contribution of natural and hatchery origin to adult recruits	

Core Monitoring Programs

This section describes each of the core monitoring programs, including program objectives, methods, and expected results. These core monitoring programs will be implemented annually by the co-managers as part of this stock management plan and funded through the co-managers annual fish management programs. Additional monitoring elements that could be implemented under each program but are not currently funded are described in the following section, *Additional Monitoring and Studies*.

Adult Catch and Escapement Monitoring

Purpose

The adult catch and escapement monitoring program is a critical core component of the Nisqually Chinook stock management plan. Effective enumeration of the total natural and hatchery Chinook run to the river, catch by treaty and sport fisheries, and the escapement of both components to the spawning grounds are direct effectiveness measures of the management strategies contained within the plan.

Methods

The methods and tools described below will be implemented to support the adult catch and escapement monitoring program. The methods are presented by monitoring variable: river catch and adult escapement and composition (basin-wide, upstream of the Centralia Diversion Dam, and downstream of the dam). Additional monitoring elements for catch and escapement, dependent on available funding, are described in the *Additional Monitoring* section below.

Nisqually River Catch in Treaty and Sport Fisheries

The treaty net fishery will be sampled for mark, coded-wire tag, age, size, and sex and to estimate the contribution of natural-origin fish to catch consistent with previous monitoring years. At least 20% of the catch will be sampled for marks, though actual sampling is expected to be much higher.[1] Estimated catch of natural-origin Chinook is based on counts of unmarked Chinook (intact adipose fin and no coded-wire tag) in the catch after subtracting unmarked hatchery-origin Chinook counts based on a mark rate for a given run. Hatchery-origin Chinook are nearly all (greater than 95%) marked (adipose-fin-clipped or coded-wire-tagged). The hatchery mark rate for a run is computed annually based on the number of unmarked, untagged Chinook that are sampled in the hatcheries. The sampling assumes that all Chinook entering the hatcheries are of hatchery-origin.

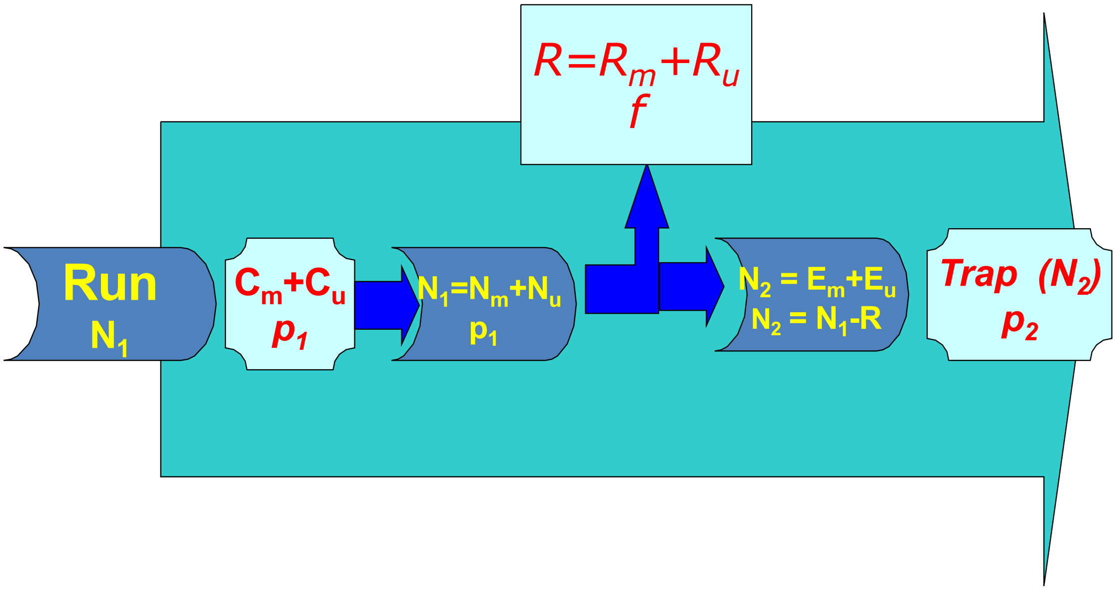
The sport fishery will be monitored through the use of Catch Record Cards that report harvest of marked and unmarked Chinook consistent with previous monitoring years. Total encounters, which comprised landed and unlanded catch, will be estimated from years of Catch Record Cards and creel study years.

Nisqually Watershed-Wide Adult Escapement and Composition

Chinook escapement to the Nisqually River will be estimated using a change-in-ratio (CIR) method (Seber 1982). The following description of the CIR methodology for calculating escapement was updated from a January 30, 2013 memo from Marianna Alexandersdottir,

[1] Sampling over the past [pending] years has averaged 45%.

Northwest Indian Fisheries Commission biometrician. The approach will continue to evolve as improved escapement estimation methods become available.



The CIR estimator relies on the fact there are two subpopulations that separate spatially through time. The Chinook run entering the river is comprised of the two subpopulations, the hatchery run and the natural run. The hatchery run separates from the natural run at the two hatcheries. Further, nearly all hatchery fish are marked with an adipose fin clip that allows visual detection as to whether the fish are hatchery-origin recruits or natural-origin recruits. The proportion of marked Chinook upstream of the hatcheries will be estimated based on counts at an adult fish trap in the Centralia Diversion Dam fish ladder (adult trap). In the event that the trap is not functioning or usable, other data collection devices will be used to calculate the final proportion for the change-in-ratio estimate. The total number of Chinook salmon entering the river (N_1) is estimated using the CIR method by,

$$\hat{N}_1 = \frac{\hat{R}(\hat{f} - \hat{p}_2)}{\hat{p}_1 - \hat{p}_2}$$

where,

- N_1 = total estimate of abundance
- R = removal of Chinook by fisheries and hatchery, R is the sum of marked and unmarked removals.
- f = proportion of total removals that are marked
- p_1 = proportion below hatchery that is marked (estimated from sample of tribal fishery below hatchery)
- p_2 = proportion above hatchery that is marked (estimated from sample at the adult trap or from sampling fish using a different live capture method)

The variance of the number entering the river is estimated by,

$$\text{var}(\hat{N}_1) = \frac{\hat{N}_1^2 V(\hat{p}_1) + \hat{N}_2^2 V(\hat{p}_2) + \hat{R}^2 V(\hat{f}) + (\hat{f} - \hat{p}_2) V(\hat{R})}{(\hat{p}_1 - \hat{p}_2)^2}$$

Escapement Estimate

The total escapement of Chinook is estimated by subtracting the in-river fishery and hatchery removals from the estimate of abundance entering the river

$$\hat{N}_2 = \hat{N}_1 - \hat{R}$$

Where N_2 represents the escapement and has a variance approximated by

$$\text{var}(\hat{N}_2) = V(\hat{N}_1) + V(\hat{R})$$

The escapement of Chinook above the CDDFL is estimated using the trap census count (TC) of all Chinook encountered. The escapement of Chinook below the CDDFL (BT) is calculated by subtracting the total escapement ($\hat{N}_2$) from the trap count (TC).

$$BT = \hat{N}_2 - TC$$

TC can be converted to escapement above trap by subtracting any removals. The proportion marked at the CDDFL is used to separate the escapement between marked and unmarked.

Proportion Marked

The proportion of marked (adipose fin clipped) fish in the population is estimated in the fishery (p_1) below the hatchery and at the trap (p_2) by,

$$\hat{p}_i = \frac{n_{i,m}}{n_{i\bullet}}$$

and,

$$\text{var}(\hat{p}_i) = \frac{\hat{p}_i(1-\hat{p}_i)}{n_{i\bullet} - 1}$$

where,

$n_{i,m}$ = number of marked fish observed in sample i, i = 1,2

$n_{i,.}$ = number of fish in sample i, i = 1,2

Removals

The total removed, R, is estimated by summing harvest and hatchery removals,

$$\hat{R} = \sum_{i=1,s} \hat{C}_i + \hat{H}$$

where,

C_s = catch in fishery in stratum s (above or below hatchery or sport fishery)

H = hatchery removals

And the variance of the removals is the sum of the variances of each component. The variance of a single component may be zero, e.g. for the hatchery removal where all rack returns are expected to be counted and sampled for mark status.

In the fishery strata, the total marked removals cannot be counted and the proportion marked in each of these components will be an estimate as shown in Eqs 5 and 6 from a sample from that stratum. The number marked is then estimated by:

$$\hat{C}_{s,m} = \hat{p}_{s,m}\hat{C}_s$$

and the variance by,

$$\text{var}(\hat{C}_{s,m}) = V(\hat{p}_{s,m})C_s^2 + \hat{p}_{s,m}^2 V(\hat{C}_s) - V(\hat{p}_{s,m})V(\hat{C}_s)$$

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The total marked removal is then the sum of the estimates of the marked removals and the variance the sum of the variances.
The estimate of the proportion marked in the total removal is estimated by:

$$\hat{f} = \frac{\sum_{i=1,s} \hat{C}_{i,m} + \hat{H}_m}{\hat{R}} = \frac{\hat{R}_m}{\hat{R}}$$

and variance is:

$$\text{var}(\hat{f}) = \hat{f}^2 \left[\frac{V(\hat{R}_m)}{\hat{R}_m^2} + \frac{V(\hat{R})}{\hat{R}^2} \right]$$

CIR Assumption of Equal Distribution of Marked to Unmarked above Hatcheries

The CIR method assumes an equal distribution of marked to unmarked Chinook in the spawning grounds above the hatcheries. The composition of marked to unmarked will be measured at the CDDFL and applied to the total escapement. Carcass surveys conducted just below CDDFL and at the lower Mashel River from years 2004 to 2013 do not indicate significant differences in composition between the two reaches (Table 5-2) for any year (two-tailed test P>0.05). Additional carcass surveys will be conducted below the CDDFL in order to validate this assumption. If the composition of marked to unmarked is significantly different between the trap counts and the carcass recoveries below the trap, then the proportion below the trap will be used to correct for the below trap escapement estimate.

Table 5-2. Carcass Recovery Survey Results (2004–2013)

	Nisqually River RM (26.2 to 21.9)				Mashel River (RM 3.2 to 0.0)			
Year	Marked	Unmarked	Total	% Marked	Marked	Unmarked	Total	% Marked
2004	22	20	42	52%	No Data			
2005	2	0	2	100%	62	66	128	48%
2006	56	13	69	81%	4	1	5	80%
2007	34	24	58	59%	54	59	113	48%
2008	77	57	134	57%	52	49	101	51%
2009	7	2	9	78%	35	15	50	70%
2010	18	7	25	72%	36	10	46	78%
2011	23	5	28	82%	63	17	80	79%
2012	17	8	25	68%	19	5	24	79%
2013	0	6	6	0%	4	10	14	29%

Carcass Recovery Surveys

Carcass recovery surveys will be conducted to validate the CIR assumption of even composition of marked and unmarked Chinook on the spawning grounds and to monitor trends in adult distribution. The surveys will consist of two index reaches (Figure 5-1), which have been surveyed since 2004, and secondary surveys to increase spatial coverage.
The two index surveys will be conducted weekly and can be used to calculate a secondary escapement estimate consistent with historical methods for comparison to the CIR method.

- Mashel River from Highway 7 Bridge to Mashel Mouth (RM 3.2 to 0.0)

- Nisqually River from the Centralia Diversion Dam to McKenna Bridge (RM 26.2 to 21.9).

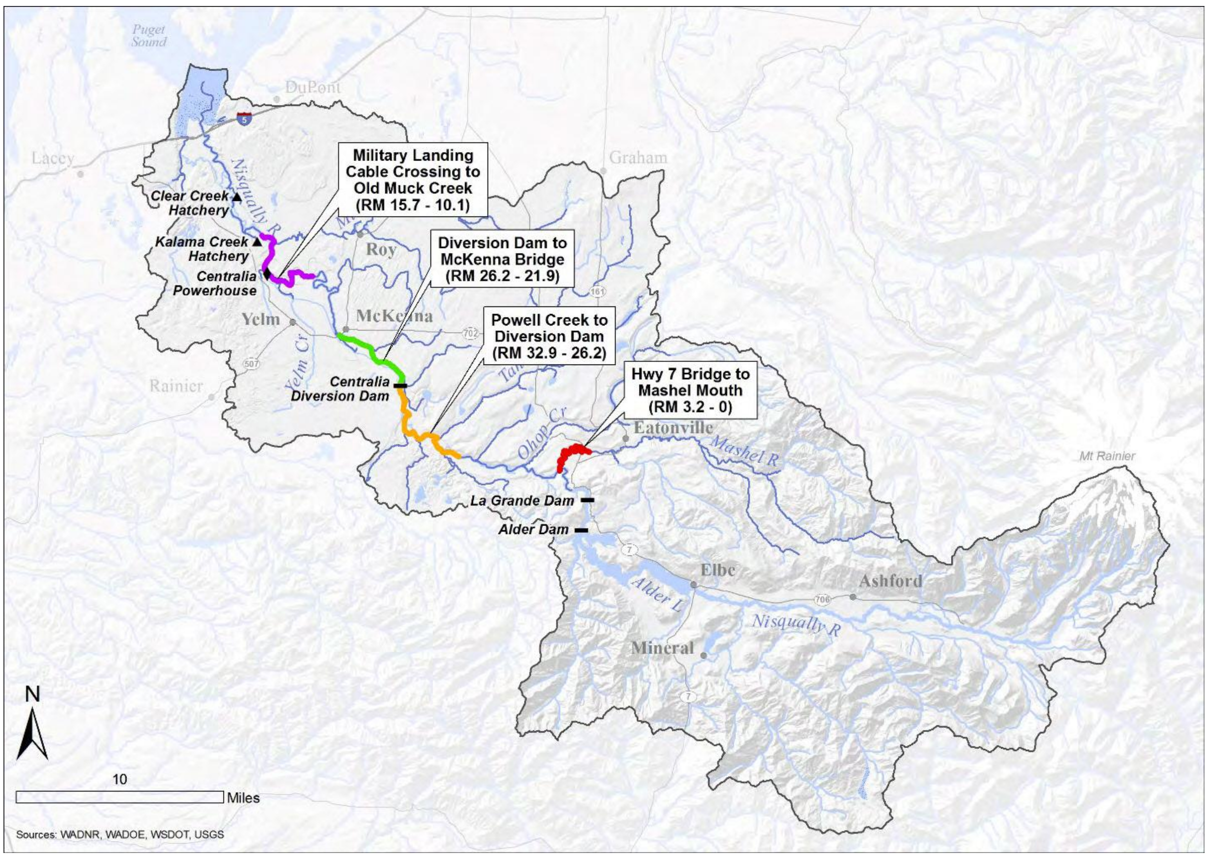
The index reach based escapement method was developed in the 1980s and uses the following equation:

$$Escapement = 6.81 * ((2.5 * PeakCoundMainstem) + PeakCountMashel)$$

Surveys will also be conducted in two additional reaches (Figure 5-1), secondary to the index reaches, to further inform understanding of the movement and spawning patterns of natural-origin Chinook, hatchery-origin Chinook, and Chinook trucked and released during the Colonization phase.

- Nisqually River from Powell Creek to the Centralia Diversion Dam (RM 32.9 to 26.2)
- Nisqually River from the Military Landing to River Bend Campground (RM 15.7 to 10.1)

Figure 5-1. Carcass Recovery Survey Locations



Expected Results

The effective enumeration of the Treaty catch, sport catch, and escapement is a key monitoring program for gauging the effectiveness of the stock management actions through all recovery phases. During colonization, escapement is the primary explanatory variable for determining the Nisqually watershed's capacity to support juvenile Chinook production and during the local adaptation and viable population phases, escapement becomes the key management target driving harvest decisions. Additionally, after the colonization experiment sunsets, the magnitude and distribution of hatchery strays is an essential input for tracking PNI and the recovery trajectory of Nisqually Chinook.

Juvenile Freshwater Monitoring

Purpose

The juvenile monitoring program is intended to provide unbiased estimates of abundance, migration timing, and body size to inform freshwater productivity, capacity, and juvenile life-history estimates. When combined with adult spawner estimates, the juvenile abundance data facilitate a stock-recruit analysis of freshwater productivity and capacity.

Freshwater productivity, capacity, and juvenile life history are determined as follows:

- Productivity: Number of outmigrants per natural spawner
- Capacity: Number of outmigrants by life stage
- Juvenile life history: Relative abundance of outmigrants by life stage

Methods

The methods and tools described below will be implemented to support the juvenile freshwater monitoring program.

The outmigrant trap operated by WDFW on the mainstem Nisqually River will continue to be operated to estimate abundance, timing, life stage, and size of juvenile migrants. The trap, an 8-foot-diameter rotary screw trap, located at RM 12.8, approximately 100 meters upstream from the Centralia Powerhouse (Figure 1-2). This site, selected for its yield of relatively high catch efficiencies and location upstream of the primary hatchery release locations (Figure 5-2), has been monitored since 2009. The trap will continue to be installed annually in mid-January and operated continuously through approximately mid-August. During some time periods, high river conditions and recreational use of the river preclude trapping operations.

The trap will continue to be checked at least daily, and more frequently during peak migration periods and high-flow events. All salmonids are identified to species, counted, and checked for previous fin clips and dye marks. Chinook salmon are classified as either subyearlings or yearlings. Yearlings are identified by body size (larger than subyearlings), faint parr marks, and silvery appearance. In some cases, scale samples for age determination are collected to confirm subyearling and yearling classifications. Fork length is collected from every tenth fish marked for release in efficiency trials and all recaptured fish.

A single-trap, stratified mark-recapture study design will be used to estimate trap efficiency throughout the season (Volkhardt et al. 2007). Each week, newly emerged subyearling Chinook salmon are batch marked Monday through Thursday with Bismarck Brown-Y dye (~ 10 mg/L) to evaluate recapture Tuesday through Monday. Larger subyearlings and yearling Chinook are marked with week-specific fin clips. All fish are broadcast released approximately 1.6 km upstream of the trap to ensure complete mixing of the mark groups.

Abundance will be estimated using the following general approach.

1. Estimate missed catch and associated variance during trap outages using catch rates before and after the outage.
2. Consolidate consecutive weekly efficiency trial data into strata with similar recapture rates using a G-test test of homogeneity (Sokal and Rohlf 1981).

3. Estimate abundance and associated variance using a modified Petersen method (Carlson et al. 1998).

Klungle et al. (in prep) provide a detailed explanation of methods and equations used to estimate abundance.

A series of spawner-juvenile recruit models will be fitted, using the total number of spawners to predict the number of juveniles within each cohort. These models will be used to evaluate the productivity and capacity parameter values of the population. The initial aim is to determine whether the relationship between spawners and juveniles follows a linear, density-independent relationship by which more spawners yield more juveniles with no evidence of an upper limit, or an asymptotic, density-dependent relationship with an upper limit to juvenile production at higher spawner abundances. If juvenile production follows a density-dependent relationship, capacity and the number of spawners needed to reach that capacity are estimated. Three different abundance variables will be explored: fry component only, parr component only, and total number of subyearlings (fry and parr). For each response variable, a density-independent, intercept-only model of constant production will be compared to a density-dependent model (e.g., Ricker, Beverton-Holt, or Hockey Stick).

Expected Results

The outmigrant trap has been operated as described above since 2009; operations will likely remain unchanged across the recovery phases.

From 2009 to 2016, the juvenile monitoring yielded abundance estimates ranging from 2,868 to 408,158 subyearling[2] Chinook, with coefficients of variation[3] ranging from 3.5 to 20.4% (Klungle et al. in prep), and 240 to 15,240 yearling Chinook, with coefficients of variation ranging from 14.0 to 139.1 % (Klungle et al. in prep). Thus, despite the inevitable trap outages, there is a high confidence level of producing reasonably precise abundance estimates (coefficients of variation < 15% in most years) of subyearlings, the life-history type that tends to predominate in the Nisqually, during the recolonization experiment and beyond.

Based on results from smolt trap monitoring in the Skagit and Green rivers (Zimmerman et al. 2015; Anderson and Topping in review), density-dependent productivity of subyearling parr and yearlings density-independent productivity of subyearling fry are expected to be observed. Throughout Puget Sound, subyearling fry abundance typically continues to increase with increasing numbers of spawners, whereas subyearling parr reach a maximum, asymptotic abundance with increasing numbers of spawners. Where yearlings are observed, their productivity appears to be density-dependent. Thus, although the Skagit and Green rivers in Puget Sound must have some carry capacity for production of subyearling fry based on the quantity and quality of spawning habitat, it does not appear that adult abundances commonly reach the level that would invoke such limits.

In the Nisqually watershed, downstream migrating fry would have the opportunity to rear in the tidally influenced delta for weeks to months prior to movement into Puget Sound proper. Thus, estimating the carrying capacity of the delta, particularly its ability to provide rearing habitat for small-bodied Chinook salmon migrants, is a complement to proposed estimates of freshwater capacity. Carrying-capacity estimates of the Nisqually delta will be conducted if additional resources become available, as described below under *Additional Monitoring and Studies*.

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[2] Two broad categories of subyearling Chinook salmon are typically observed: small newly emerged fry more than 45 mm migrating January through March, and larger reared parr ≥45 mm migrating June through August (Klungle et al. in prep).

[3] Higher coefficients of variation were associated with low abundance years.

Nearshore Puget Sound likely also has some capacity for rearing small Chinook salmon, though without systematic monitoring surveys in these habitats, this life stage would be combined with all others in an adult-to-adult estimate of capacity.

Juvenile Nisqually River Delta Monitoring

Purpose

The purpose of the juvenile Nisqually delta core monitoring program is to track juvenile life-history diversity (temporal and spatial) and relative density across distinct delta habitat zones. Additional monitoring would also provide estimates of delta productivity and delta capacity. Data on the capacity of the delta to support juveniles is important to place the Chinook habitat use data in context each year, especially since delta capacity is changing following restoration. However, this sampling is very intensive and is dependent on additional resources (see *Additional Monitoring and Studies*).

Methods

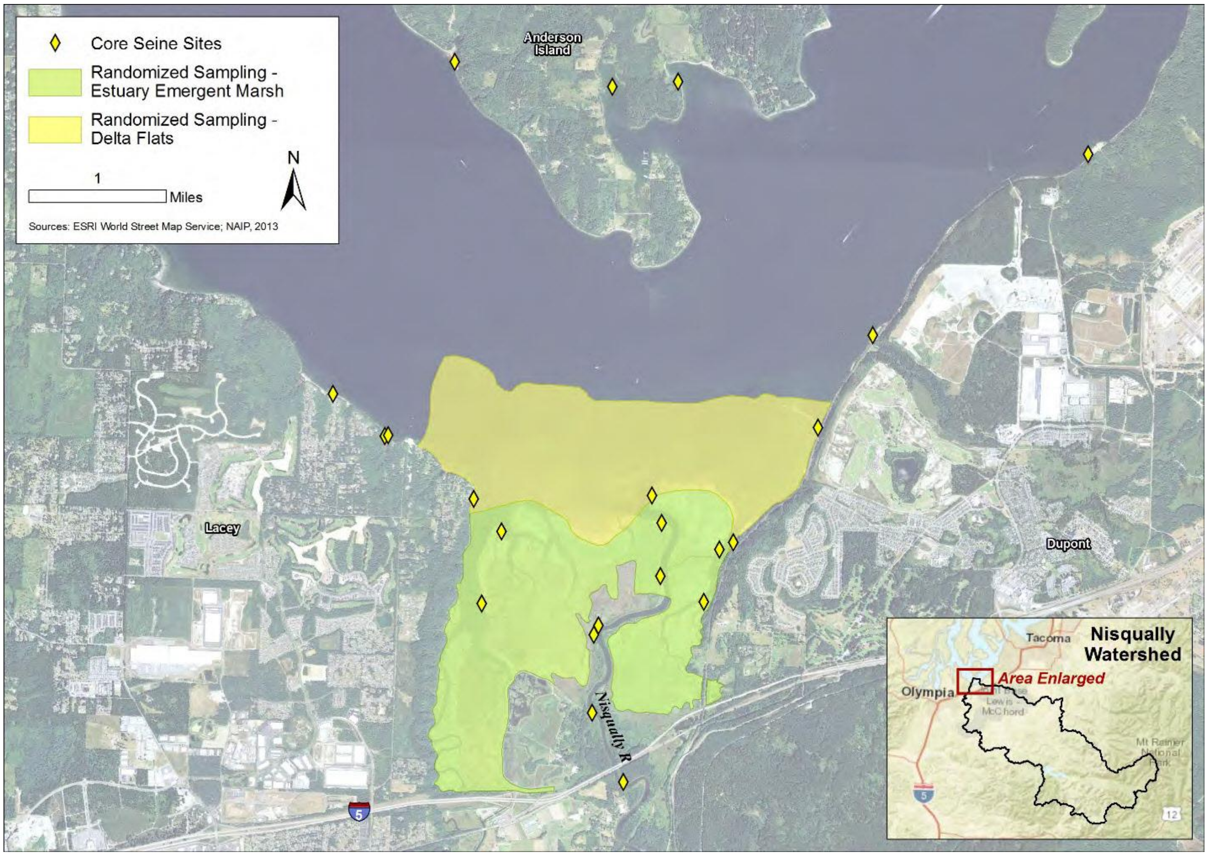
The methods and tools described below will be implemented to support the juvenile delta monitoring program.

Biweekly beach seining will be conducted from January/February through October in all habitat zones (freshwater tidal, forested riverine tidal, emergent forested transition, estuarine emergent marsh, delta flats, and nearshore) to measure relative abundance in time and space.[4] Seining sites in all habitat zones, matching sites that have been monitored regularly in previous years informs understanding of spatial and temporal diversity and long-term comparisons. Catches at seine sites will be converted into density estimates[5] to compare densities of fish through time and space and look for effects of different-sized outmigrations on abundance. Sites that have been monitored in previous years will be selected from each habitat zone as index sites (one to two per zone), while additional sites (about two per zone) will be randomly selected for additional sampling to provide a representative sampling of fish density across the entire Nisqually delta (Figure 5-3). The methods are modeled after the Skagit River Estuary Intensively Monitored Watershed Project (Greene and Beamer 2011).

Figure 5-2. Beach Seine Sites

[4] This continues long-term monitoring that the Nisqually Indian Tribe has been conducting since 2003 (Ellings and Hodgson 2007).

[5] Using area fished estimates computed with a Trimble GPS on board the sampling boat.



Data collected at seine sites include counts of each fish species caught, lengths and weights for 10 Chinook per site visit (if present), and water quality measures including temperature, salinity, and dissolved oxygen. Captured Chinook and coho salmon will be checked for an adipose fin clip and scanned for a coded-wire tag. Some of the Chinook and coho with a coded-wire tag will be sacrificed to recovery the tag to determine origin.

Expected Results

Post-restoration monitoring data in the Nisqually delta (2009–2012) have detected rapid, landscape-scale improvements in habitat suitability for juvenile Chinook and other salmon, with some sites exhibiting greater functionality than others. Immediate benefits appear to be driven by the connectedness of restoring habitat and its invertebrate prey productivity (David et al. 2014; Ellings et al. 2016).

Simenstad and Cordell (2000) laid the foundation for a three-tiered monitoring framework by which restoration success criteria are evaluated for the Nisqually delta. This framework is based on long-term measures of opportunity, capacity, and realized function.

- Opportunity is related to the amount of habitat available and physical features including how accessible the habitat is.
- Capacity is related to the types and abundance of prey items available for forage in newly-available habitats.

- Realized function describes the direct physiological responses of fishes that result from improvements in habitat and prey availability.

This framework is used to determine success of the restoration program by asking if juvenile salmonids are successfully accessing and benefiting from restored estuarine habitat.

Detailed monitoring results from intensive post-restoration monitoring in the Nisqually delta are described in Table 5-2. The success of the Nisqually delta restoration appears to be more functionally driven, as opposed to structurally driven. For example, two restored sites (known as 2006 Restoration and 2009 Restoration) have had different results. Juvenile Chinook were captured at the 2006 Restoration site in less than half of the times sampled and had emptier guts and smaller size than those captured at the 2009 Restoration site where they were present most of the times sampled (Ellings et al. 2016; Davis et al. in press). The 2006 Restoration site shares characteristics with the sampled reference sites in terms of channel morphology and vegetative composition; however, this site is less functional than the 2009 Restoration site (Table 5-2) most likely due to its distance from the mainstem Nisqually (Ellings et al. 2016). On the other hand, the 2009 Restoration site is still physically degraded, but it is used throughout the rearing season by Chinook and produces just as much (if not more) prey as the reference sites (David et al. 2014; Ellings et al. 2016; Davis et al. in press).

Chinook densities will be compared among sample sites with different connectivity to the Nisqually River mainstem. We hypothesize that at lower annual outmigration abundances as reported by the outmigrant trap, densities will be highest at sites with good connectivity and easy access from the mainstem (e.g., Animal Slough) compared to less well-connected sites. With higher abundances of outmigrants, densities across sites are expected to be more similar, as juvenile Chinook spread out across the delta to occupy less well-connected sites. Chinook densities will also be compared to annual outmigration abundance to look for evidence of an asymptote in densities, suggesting an upper limit to the number of Chinook that occupy a site. In addition to densities, Chinook lengths will be compared to annual outmigration abundance to look for effects of higher densities on growth.

Table 5-2. Nisqually River Delta Monitoring Metrics

Variables	Historic Marsh (Reference Sites)	2006 Restoration Site (Red Salmon Slough)	2009 Restoration Site (Billy Frank Jr. Nisqually National Wildlife Refuge)	Nisqually Delta-Wide
Opportunity	• Channel depths remained stable • Sites are generally closest to the Nisqually mainstem • Sites are available 47–67% of the time • Easiest access at mean tidal level (~0.6 tortuosity ratio) • Temperatures remained stable • Highest salinity (10–20 ppt) • Full coverage of high salt marsh vegetation • 62–93% proportional presence for juvenile Chinook • 68–87% proportional presence for juvenile chum	• 78,000 m^2 of tidal channels added to the Nisqually Delta (including Pilot and Phase I) • Channels became marginally deeper through time (-1.6 cm/year) • Temperatures remained stable • Lowest salinity (5–8 ppt) • Full coverage of high salt/brackish marsh vegetation • 32–47% proportional presence for juvenile Chinook • 50% proportional presence for juvenile chum	• 450,000 m^2 of tidal channels added to the Nisqually Delta • Channels became substantially deeper through time (-7.4 cm/year) • Up to three separate accessible paths at high tide, with a tortuosity ratio of 0.84 • Gradual temperature decline (~2°C) at seaward sites • Broad range of salinity values (5–20 ppt) • Primarily mudflat with some low marsh vegetation • 80–89% proportional presence for juvenile Chinook • 42% proportional presence for juvenile chum	• 42% increase in channel area (1.6 million to 2.3 million m^2) • 131% increase in channel length (37,000–85,000 m) • 126% increase in channel edge (76,000–173,000 m) • Tidal channel accessibility increased from 30 to 75% of the tidal cycle
Capacity	• Post-restoration increases in amphipods, potentially due to organic matter exchange • Very high proportion of arachnids and hemipterans in terrestrial drift	• Post-restoration increases in amphipods, potentially due to organic matter exchange • Terrestrial prey community highly diverse	• Immediate post-restoration increases in copepods and amphipods, decreases in insect larvae • Terrestrial prey community dominated by dipteran flies • Prey biomass equivalent to or greater than other sites, primarily comprising terrestrial taxa	• Delta-wide increases in benthic, terrestrial, and aquatic biodiversity may support multiple salmon species and life history strategies

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Variables	Historic Marsh (Reference Sites)	2006 Restoration Site (Red Salmon Slough)	2009 Restoration Site (Billy Frank Jr. Nisqually National Wildlife Refuge)	Nisqually Delta-Wide
Realized Function	• Prey energy availability frequently topped 1 million kJ at the reference sites	• Lowest prey energy availability (< 250,000 kJ) of sites monitored	• Estimated 6 million kJ available prey energy at any given time (enough to feed ~ 900,000 juvenile Chinook salmon for 1 week)	• Juvenile Chinook diets were almost entirely comprised of amphipods, dipterans, and mysids (when calculated as dry-weight biomass) • Otolith-derived growth rates did not differ among sites • Evidence for recant delta entrants using reference sites more frequently (due to their greater connectivity)

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Hatchery Monitoring

Purpose

The purpose of hatchery monitoring is to provide an annual accounting of the adult returns to the hatcheries, the number of Chinook used for broodstock, in-hatchery and post-release survival, and number Chinook released by program component including size at release, time of volitional release and end of release period, and number adipose fin-clipped and coded-wire tagged. This accounting of hatchery program attributes for broodstock, fecundity, mating, and in-hatchery and post release survival will be used to update management objectives for hatchery broodstock and release. The count of hatchery-origin and mark status of adults entering hatcheries will be used to test and update plan assumptions regarding the collection of hatchery-origin adults at the hatchery ponds, the percentage of the hatchery escapement not entering hatcheries, and annual mark rates of the hatchery run.

All of the variables are measured through direct enumeration or classification by hand or by machine as part of hatchery operations. They will be reported by hatchery staff in the annual hatchery report. A summary of all hatchery operations and data collection conducted as part of hatchery operations are presented in the Nisqually River Chinook Hatchery and Genetic Management Plan (currently being developed).

Methods

The following metrics will be monitored at the hatcheries:

- Number of adults and jack counts to hatcheries and McAllister Springs/Creek plus outlet creeks and McAllister Creek
- Number of hatchery-origin adults used for broodstock
- Number of natural-origin adults and jacks collected for broodstock
- Survival rates (surviving to spawn) natural-origin used for broodstock
- Number of surviving natural-origin adults and jacks used for broodstock
- Fecundity hatchery- and natural-origin used for broodstock
- Age composition hatchery- and natural-origin
- Survival rates green egg to eyed egg
- Survival rates eyed egg to ponding
- Survival rates ponding to release
- Number of juveniles released, date of release, size of juveniles at release, and number adipose fin clipped and number coded-wire tagged.

Expected Results

Historical results from the Clear Creek and Kalama Creek hatcheries were used to shape program broodstock and number of Chinook released (see HGMP in development). The two hatcheries have been operated as isolated programs to support harvest. As such, hatchery monitoring focused on information to report size of the release and number marked in the release and monitor post-release survival. In-hatchery survival was monitored to adjust broodstock requirements.

The hatchery monitoring program will have a greater emphasis as conservation issues will have a higher priority, particularly when natural-origin adults are collected for broodstock.

Habitat Monitoring

Purpose

The purpose of the habitat monitoring program is to track progress implementing the habitat actions detailed in the Nisqually Chinook Recovery Plan (2001) and subsequent 3-and 4-year work plans (http://www.psp.wa.gov/salmon-four-year-work-plans.php). Habitat gains that result from protection and restoration projects can be characterized using a variety of variables depending on the type of project and location within the watershed.

Table 5-3 lists variables that will be monitored for the different types of habitat recovery projects through time.

Table 5-3. Variables Monitored for Habitat Restoration Projects by Type

Project Type	Monitoring Variable
Estuary Restoration	Acres re-connected to tidal exchange
Floodplain Restoration	Acres of floodplain re-connected to fluvial processes
Mainstem and Tributary Protection	Miles of shoreline protected from development Acres of floodplain protected from development
Watershed Process Protection	Acres of forestland protected or converted from commercial forestry to Ecosystem Services based management
Instream Habitat Diversity Restoration	Number of engineered logjams constructed miles of stream treated
Riparian Restoration	Acres of riparian planted and/or treated for invasive species
Barriers	Number of fish barriers removed Miles of stream made accessible

Methods

All variables will be measured using a combination of post project as-built reports, field visits, and remote sensing based mapping. Project outcomes will be reported using Habitat Work Schedule, an online habitat tracking database (http://hws.ekosystem.us/site/220).

Expected Results

The core habitat monitoring program will enable the Nisqually Chinook Recovery Team to track progress made toward implementing the habitat recovery goals listed in the Nisqually Chinook Recovery Plan.

Stock Recruitment Analysis

Purpose

The purpose of the Stock Recruitment analysis is to assess the productivity and abundance of Nisqually River Chinook by brood year. Results of the analysis will be used by the Nisqually technical work group to evaluate brood-year abundance and recruitment rates. The Nisqually work group will use this information to determine if the population can transition to Local Adaptation and what revisions in strategies are needed to make the transition.

Methods

The stock recruitment analysis estimates natural-origin adult abundance to the river, spawner abundance and composition, and survival rates of juvenile outmigrants compared to adult recruits to the river.

Natural-Origin Adult Abundance to River

Natural-origin adult abundance in the terminal run will be calculated as the sum of the following:

- In-river catch and nonlanded mortality (released fish) estimates, described in *Adult Catch and Escapement Monitoring*
- Natural-origin adults removed for broodstock[1]
- Watershed-wide natural spawning escapement estimates of natural-origin adults are described in *Adult Catch and Escapement Monitoring*

Survivals Rates (Juvenile Outmigrants to Adult Recruits to River)

Survival rates will be based on the following:

- Outmigrant estimates, described in *Juvenile Freshwater Monitoring*
- Estimates of natural-origin adult recruits to river, described in *Adult Catch and Escapement Monitoring.*

Recruitment Rates (Spawners to Adults by Brood Year)

Recruitment rates will be based on the following.

- Parent natural spawning abundance by origin estimates, described in XX or based on XX estimates described in *Adult Catch and Escapement Monitoring*.
- Terminal natural-origin run allocated to brood year, based on estimates of total age of adults in annual run (catch plus escapement) described in *Adult Catch and Escapement Monitoring*

Nisqually Chinook Genetics Assessment

Purpose

The purpose of the Nisqually Chinook Genetics Assessment is to evaluate the response of the stock to plan implementation through the following analyses:

1. Estimate adult abundance using trans-generational genetic mark recapture (tGMR)
2. Estimate effective breeders by origin
3. Estimate relative contribution to juvenile production for the three adult types in the escapement (natural origin spawners, hatchery origin spawners, and hatchery recruits trucked to the upper Nisqually)
4. Conduct a genetic based brood year reconstruction to evaluate relative contribution of natural and hatchery origin to adult recruits

[1] This will occur as part of the integrated hatchery program implemented during the Local Adaption phase.

Methods

The proposed genetics assessment plan during the Colonization phase is summarized in Table 5-4.

Adult Abundance

Tissue samples from adult spawners and subyearling migrants will be collected each year. Genetic mark-recapture (GMR) will be used to estimate spawning escapement from those samples (Pearse et al. 2001, Rawding et al. 2014) as funding permits.

GMR escapement estimates will be compared to those from the change-in-ratio method (proportion of hatchery fish in harvest samples downstream of Clear Creek Hatchery compared to proportion of hatchery fish in samples upstream of Clear Creek Hatchery, either collected at the weir or from spawning ground surveys farther upstream) used to estimate spawner abundance in the Nisqually River. The coefficient of variation (CV) for the GMR estimate should be less than 15% to meet United States-Canada reporting requirements, as has been found for GMR estimates in other systems (Coweeman, Stillaguamish, Nooksack). The CV of change-in-ratio method will be compared as will the absolute estimates of spawning escapement.

Estimates of Effective Breeders

Cohorts of juveniles sampled for the GMR study will be used to estimate effective population size of natural production in the Nisqually River by examining temporal variation in allele frequency between the cohorts (Waples 1989). The effective population size estimate will give insight to the relative importance of genetic drift and natural selection in the population's response as it continues to adapt to the river. If Ne is low, genetic drift will take on outsized significance in the shaping the population's future. In addition, for each individual cohort, effective number of breeders (Nb) will be estimated using the method of Wang (2009). The effective number of breeders will be used with the escapement estimate (census population, Nc) to estimate the proportion of escapement contributing to natural production (Nb/Nc ratio). Estimates of the number of breeders contributing will give insight to the potential for inbreeding as the population persists and also will give insight to the amount of production to be expected from a particular level of escapement.

Contribution by Type to Juvenile Production

In addition to the GMR study outlined above that is funded for samples representing brood-years 2012–2014, in the future, tissue samples will continue to be taken from each category of adults spawning in the Nisqually (natural-origin fish intercepted at the Centralia Diversion dam, hatchery-origin fish trucked to the upper Nisqually to increase spawner density, and also samples taken from hatchery- and natural-origin carcasses collected above and below the Centralia Diversion Dam). 50% of total spawners in the Nisqually are expected to be sampled. Samples will also be taken from up to 3000 natural-origin smolts handled at the Nisqually smolt trap downstream. Processing these samples for DNA analysis will be dependent on ability to obtain funding in the future. Should funding be available, production of smolts at the trap will be able to be assigned to natural- and hatchery-origin spawners above the smolt trap and potentially above and below the Centralia Diversion Dam.

The proportion of hatchery-identified parents (verified through identification of progeny) will be compared to the proportion of hatchery-identified carcasses. A consistent difference across years between proportion of hatchery-origin parents and proportion of hatchery-origin carcasses, by sex, would be consistent with a difference in reproductive success of hatchery vs. natural fish. Methods to this point will follow those outlined in Rawson and Crewson et al. (2017). Through time, if parentage studies continue, it may become possible to determine if there are differences in reproductive success of natural-origin progeny of hatchery-origin spawners and natural-origin progeny of natural-origin spawners. Such a difference that is maintained through generations would be consistent with a heritable difference in reproductive success of hatchery- and natural-origin spawners.

Contribution by Origin to Adult Recruitment (Adults Back to Nisqually River)

Over time, sampling adults for genetic mark recapture above and below the Centralia Diversion Dam will yield samples of adults that are progeny of adults sampled in previous years. Adults sampled in 2017, for instance, will be parents of 2-year old adults sampled in 2019, 3-year-old adults sampled in 2020, 4-year-old adults sampled in 2021, and 5 year-old adults sampled in 2022. Tissue from such adults will be archived from at least 7 successive years so that a cohort produced with and without pink salmon spawning in the river will have been sampled. If sampling is extended to a total of 13 successive years than pairs nonoverlapping cohorts, each spawned with and without pink salmon in the river, will have been sampled. Genetic analysis of such samples will depend upon future funding availability. Once the samples are analyzed, production of spawning adults will be apportioned to each category of spawner that has been identified: hatchery- and natural-origin adults that spawn above and below the Centralia Diversion Dam, and hatchery recruits that are trucked above the Diversion Dam.

Table 5-4. Preliminary Genetic Sample Plan

Study Year	Brood Year Spawners	Juvenile Migrants	Study Results
Year 1	1,500 adults (~250 NOS, ~250 HOS volunteers, 1,000 HOS trucked)	----	Initial genotype NOS, HOS and HOS trucked
Year 2	1,500 adults (~250 NOS, ~250 HOS volunteers, 1,000 HOS trucked)	2,000 subyearlings	Year 1 adult abundance using tGMR, # effective breeders by origin (natural-origin, hatchery-origin volunteers, and hatchery-origin truck and hauled), and relative contribution to juvenile production of three groups of spawners
Year 3	1,750 adults (~500 NOS, ~250 HOS volunteers, 1,000 HOS trucked)	2,000 subyearlings	Year 2 adult abundance using tGMR, # effective breeders by origin (natural-origin, hatchery-origin volunteers, and hatchery-origin truck and hauled), and relative contribution to juvenile production of three groups of spawners **Brood Year Reconstruction:** Age 2 recruits from Year 1
Year 4	500 adults (NOS)	2,000 subyearlings	Year 3 adult abundance using tGMR, # effective breeders by origin (natural-origin, hatchery-origin volunteers, and hatchery-origin truck and hauled), and relative contribution to juvenile production of three groups of spawners **Brood Year Reconstruction:** Age 2 recruits from Year 2 Age 3 recruits from Year 1
Year 5	500 adults (NOS)	---	**Brood Year Reconstruction:** Age 2 recruits from Year 3 Age 3 recruits from Year 2 Age 4 Recruits from Year 1
Year 6	500 adults (NOS)	---	**Brood Year Reconstruction:** Age 3 recruits from Year 3 Age 4 Recruits from Year 2

Study Year	Brood Year Spawners	Juvenile Migrants	Study Results
			Age 5 Recruits from Year 1
Year 7	500 adults (NOS)	---	**Brood Year Reconstruction:** Age 4 Recruits from Year 3 Age 5 Recruits from Year 2
Year 8	500 adults (NOS)	---	**Brood Year Reconstruction:** Age 5 Recruits from Year 3

Additional Monitoring and Studies

The following monitoring activities and directed studies would provide additional information to evaluate program assumptions and population performance. These activities are dependent on funding that has not yet been identified and are not part of the core monitoring program that will be implemented under this plan.

Adult Catch and Escapement Monitoring

Nisqually River Catch in Treaty and Sport Fisheries

- Creel surveys could be conducted to improve estimates of landed and incidental mortality of natural-origin Chinook from the sport fishery catch.
- Mark-selective treaty fishery study: test an array of potential commercial selective fishing gear for catch efficiency, incidental mortality, and fishery compatibility.
- Mark-selective sport fishery study: test for differential sport release mortality between estuary and river caught Chinook.
- Study of net dropout rate in treaty commercial fishery to improve fishery mortality estimates.

Nisqually Watershed-Wide Adult Escapement and Composition

- Historical escapement could be estimated from live and dead counts and expansion formula (Tweit 1986) and calculated to better understand bias in the historical abundance estimates.
- Carcass recovery surveys of the Mashel River above Highway 7 and along the Nisqually mainstem from the mouth of the Mashel to Powell Creek would further expand understanding of composition.
- Radio tagging and tracking of adults (hatchery- and natural-origin) captured would improve evaluation of migration and spawning behavior above and below the Centralia Diversion Dam.

Juvenile Freshwater Monitoring

No additional methods beyond those identified in the core program have been identified.

Juvenile Nisqually River Delta Monitoring

- Lampara net sampling (May to September) in the shallow open delta mudflats areas (including eelgrass bed adjacent areas), and lampara or tow-net sampling in the offshore areas adjacent to the delta would improve life-history and delta productivity estimates.

- Biweekly fyke net sampling (April to September) of sloughs in the emergent marsh zone, areas not reachable by beach seine, would improve delta capacity estimates. As with the beach seine sampling, index fyke trap sites would be chosen from the five sites with data for multiple years, along with a limited number of randomly selected new sites. Index and new sites would be chosen to represent different levels of connectivity to the mainstem Nisqually and to represent the geography of the area, including the Red Salmon Slough and McAllister Creek sides of the delta. Catch and density records would be adjusted for trap efficiency as measured with mark-recapture sampling at each trap on one sampling day.
- Benthic core samples, invertebrate fallout trap samples, and neuston tow samples could be collected monthly from April to July to quantify prey from the substrate, the terrestrial environment, and the water column, respectively.
- PIT tags to mark and recapture individual fish also be used to study fish movements within the delta and timing patterns between tagging (at the outmigrant trap, hatchery, or hatchery off-station release site), entry into the delta, and capture or presence at an antenna in the delta. PIT tag recapture rates in the delta and differences between recaptures at well-connected mainstem sites and less well-connected sites could be compared to outmigrant trap annual estimates to look for evidence of differences in habitat use and dispersal with differences in abundance of juvenile Chinook entering the delta.
- Otoliths collected from returning adults to determine the delta residence patterns of adults that survived to return could be paired with juvenile otolith sampling to characterize residence time and growth of juveniles and to compare life-history types between juveniles and successfully returning adults.

Hatchery Monitoring

No additional methods beyond those identified in the core program have been identified.

Stock Recruitment Analysis

Natural-Origin Adult Abundance to River

- Creel surveys to improve estimates related to the sport fishery catch would also improve estimates of natural-origin adult abundance to river.

Survival Rates (Juvenile Outmigrants to Adult Recruits to River)

- Otolith microchemistry for growth, residence time, and life-history types surviving to adult return would improve estimates of survival rates.

Habitat Monitoring

A habitat status and trends program, as recommended in *Methods and Quality of Salmonid Habitat Monitoring of ESA Listed Puget Sound Salmon and Steelhead with Identified Critical Gaps* (Crawford 2013) would link Chinook population response to habitat recovery actions.

Chapter 6
Data Management, Record Keeping, and Reporting

Plan Monitoring Data Tracker

The monitoring program to support the Chinook management plan will be designed to collect data that supports implementation of the plan. Specifically the monitoring program will collect:

- Data to update key assumptions
- Data to update population status and trends information
- Data necessary to review and apply the decision rules for harvest, hatchery, and escapement management
- Data necessary to compute in-season biological objectives for the coming year and to review these for consistency with conservation and harvest objectives

The information that informs the plan will be gathered and analyzed from a wide variety of sources as described in Chapter 5, *Monitoring Tools and Objectives*. Some of this information is updated annually with results from specific monitoring activities and results from the previous year operations; some information may not be available for several years (e.g., genetics assessment).

The In-Season Implementation Tool (ISIT?) is a Microsoft Excel-based application that is organized to follow the outline of the APR. It includes worksheets for each of the components of the APR (key assumptions, status and trends, decisions rules, and plan objectives). Its purpose is to store and document data and assumptions, and derive annual management objectives for the operation of the Nisqually terminal fisheries, escapement, and hatchery programs. The ISIT? documents the basis for these objectives and establishes expectations for all management indicators; it also simplifies the implementation process and documents the rationale for the management actions taken each year.

Inputs to ISIT? are mostly summaries of information collected for status and trend monitoring and evaluation of key assumptions, and results from preseason and in-season forecasting models. The ISIT? tool is not a replacement for a comprehensive data system to store and manage information collected to support the plan. That data system still needs to be developed. A single database is generally inadequate to cover all monitoring activities across multiple agencies. The technical work group will need to discuss an interconnected data management system that can operate across multiple databases. The technical work group might decide to develop a data mapping system that describes the relationships among the different datasets and the pedigree of data used in the decision process.

In addition, the technical work group will need to develop and manage other tools and models (some existing such as EDT to track habitat) and some that need to be developed such as for in-season updates.

Annual Project Review

The APR workshop will be conducted each year by the technical work group, after preseason projections are available for the coming Chinook management season. The agenda will follow the four-step procedure outlined in Figure 3-1 with special emphasis on Chinook terminal area management. The APR is a science-driven process that informs the workshop participants and will result in an action plan for the coming season. This action plan will be presented as a subsequently adopted action plan and will constitute the All-H coordinated implementation component of the Nisqually Chinook Plan.

Prior to the workshop, the technical work group will meet with the various action leads to compile draft annual summaries on each of the following subjects to be available at the workshop.

- Habitat and natural production
- Terminal and preterminal harvest
- Hatchery operations
- Escapement management

The tools used to support the plan will be populated with the most recent data and analytical results prior to the workshop. The objective of the APR workshop is to address four questions.

1. Were objectives met last year and if not, why not?
2. What are trends in population status and management objectives (e.g., pHOS and PNI)?
3. How can operations be improved in terms of effectiveness and efficiency in the coming year?
4. Should management objectives be modified; are they consistent with most recent and best available science?

The technical group will use this information to review the implications of information presented in during the APR. The NCSMP technical team will review conclusions from the workshop and supporting material, and discuss alternative options for the decision rules as necessary to advance recovery. Note, the purpose of the decision rules is to ensure that the long-term goals for conservation and harvest established in the plan are met over time. A product of workshop will be a recommended action plan for operating fisheries, managing escapement, and hatchery operations in the coming year. A final task of the APR workshop will be staff assignments for year-end activities (i.e., finalizing annual reports) and for implementing harvest, hatchery, escapement, and M&E plans for the coming year.

Chapter 7
Budget

Successful implementation of this plan is dependent on adequate funding to support monitoring and evaluation components, staffing for operations, and infrastructure to implement the plan. The co-managers are coordinating technical staff and identifying additional resources to implement the plan.

Table 7-1 presents the estimated annual cost of implementing the core monitoring programs described in Chapter 5, *Monitoring Tools and Objectives*.

Table 7-1. Annual Cost Estimates for Core Monitoring Programs

Monitoring Program	Core Monitoring	Annual Cost
Adult Catch and Escapement Monitoring	Treaty net fishery sampling	$125,000
	Catch Record Cards reporting of the sport catch	N/A
	Total encounters estimated from years of CRC and creel study years	N/A
	Adult counts at adult fish trap in the Centralia Diversion Dam fish ladder	$250,000
	Carcass recoveries from priority index reaches (weekly) and nonindex reaches (biweekly)	$100,000
	Estimates of escapement, proportion marked, and removals	N/A
Juvenile Freshwater Monitoring	Outmigrant trap operation	$225,000
	Abundance estimates and stock-recruit curves	N/A
Juvenile Nisqually River Delta Monitoring	Beach seining	$150,000
Hatchery Monitoring	Hatchery staffing (Kalama Creek and Clear Creek Hatcheries)	N/A
	Seasonal staffing at McAllister Springs Release Pond	$30,000
	Adipose fin clipping and coded- wire tagging	N/A
Habitat Monitoring	Track implementation of *Nisqually Chinook Recovery Plan* Habitat Action Plan	$65,000
Stock Recruitment Analysis	Estimates	N/A
	Estimates	N/A
	Estimates	N/A
Genetics Assessment	Genetic mark recapture study	$100,000
Total average cost per year		**$1,045,000**

N/A = Denotes costs that are covered under other budgets not directly tied to this stock management plan.

Chapter 8
Literature Cited

Anderson, J. H., and P. C. Topping. In review. Juvenile life history diversity and productivity of Chinook salmon in the Green River, Washington. *North American Journal of Fisheries Management*.

Araki, H., B. A. Berejikian, M. J. Ford, and M. S. Blouin. 2008. Fitness of hatchery-reared salmonids in the wild. *Evolutionary Applications* 1(2):342–355.

Berejikian, B. A., and M. J. Ford. 2004. Review of relative fitness of hatchery and natural salmon. U.S. Dept. Commer. NOAA Tech. Memo. NMFSNWFSC- 61, 28 p.

Campton, D. E. 2004. Sperm competition in salmon hatcheries: The need to institutionalize genetically benign spawning protocols. *Transactions of the American Fisheries Society* 133(5):1277.

Carlson, S. R., L. G. Coggins Jr., and C. O. Swanton. 1998. A simplified stratified design for mark-recapture estimation of salmon smolt abundance. *Alaska Fishery Research Bulletin* 5:88–102.

Carlson, S. M., and T. R. Seamons. 2008. A review of quantitative genetic components of fitness in salmonids: implications for adaptation to future change. *Evolutionary Applications* 1(2):222–38.

Christie, M. R., M. J. Ford, and M. S. Blouin. 2014. On the reproductive success of early-generation hatchery fish in the wild. *Evolutionary Applications* 7(8): 883–896.

Curran, C. A., E. E. Grossman, C. S. Magirl, and J. R. Foreman. 2016. Suspended sediment delivery to Puget Sound from the lower Nisqually River, western Washington. July 2010–November 2011: U.S. Geological Survey Scientific Investigations Report 2016-5062. 17 p. http://dx.doi.org/10.3133/sir20165062.

David, A. T., C. S. Ellings, I. Woo, C. A. Simenstad, J. Y. Takekawa, K. L. Turner, A. L. Smith, and J. E. Takekawa. 2014. Foraging and growth potential of juvenile Chinook salmon after tidal restoration of a large river delta. *Transactions of the American Fisheries Society* 143:1515–1529

Davis, M. J., C.S. Ellings, I. Wood, S. Hodgson, K. Larsen, and G. Nakai. In press, Gauging resource exploitation by juvenile Chinook salmon (*Oncorhynchus tshawytscha*) in restoring estuarine habitat. *Restoration Ecology*.

Ellings C. E., and S. Hodgson. 2007. Nisqually Estuary Baseline Fish Ecology Study: 2003–2006. Nisqually National Wildlife Refuge and Nisqually Indian Tribe. Olympia, WA.

Ellings, C. E., M. J. Davis, E. E. Grossman, I. Woo, S. Hodgson, K. L. Turner, G. Nakai, J. E. Takekawa, and J. Y. Takekawa. 2016. Changes in habitat availability for outmigrating juvenile salmon (Oncorhynchus spp.) following estuary restoration. *Restoration Ecology* 24:415–427.

Ford, M. J. 2002. Selection in captivity during supportive breeding may reduce fitness in the wild. *Conservation Biology* 16:815–825.

Greene, Correigh M., and Eric M. Beamer. 2011. Monitoring Population Responses to Estuary Restoration by Skagit River Chinook Salmon. Intensively Monitored Watershed Project Annual Report.

Hatchery Scientific Review Group. 2014. On the Science of Hatcheries: An updated perspective on the role of hatcheries in salmon and steelhead management in the Pacific Northwest. A. Appleby, H.L. Blankenship, D. Campton, K. Currens, T. Evelyn, D. Fast, T. Flagg, J. Gislason, P. Kline, C. Mahnken, B. Missildine, L. Mobrand, G. Nandor, P. Paquet, S. Patterson, L. Seeb, S. Smith, and K. Warheit. June 2014. Revised October 2014.

Hatchery Scientific Review Group. 2009. Columbia River Hatchery Reform System-Wide Report. P. Paquet (chair), A. Appleby, J. Barr, Lee Blankenship, D. Campton, M. Delarm, T. Evelyn, D. Fast, T. Flagg, J. Gislason, P. Kline, D. Maynard (alternate), G. Nandor, P. Seidel, and S. Smith. 272 pp. http://www.hatcheryreform.us/

Klungle, M., J. Anderson, and M. Zimmerman. In prep. Nisqually River Outmigrant Juvenile Salmonid Report: 2009–2016. Washington Department of Fish and Wildlife. Unpublished draft report.

Lind-Null A., K. Larsen, K. Stenberg, and L. Wetzel. 2009. Characterization of Life History Types for Nisqually Adults Using Otolith Analysis: BY 2003. Final Progress Report presented to Nisqually Indian Tribe. December.

National Marine Fisheries Service 2006. Recovery Plan for the Puget Sound Chinook Salmon (*Oncorhynchus tshawytscha*). National Marine Fisheries Service, Northwest Region. Seattle, WA.

National Marine Fisheries Service. 2010. Puget Sound Chinook Salmon Population Recovery Approach. Puget Sound Domain Team, Northwest Region. Seattle, WA.

Nisqually Chinook Recovery Team. 2001. Nisqually Chinook Recovery Plan. August.

Nisqually Chinook Work Group. 2011. Nisqually Chinook Stock Management Plan. January.

Nisqually Steelhead Recovery Team. 2014. Nisqually Winter Steelhead Recovery Plan. July.

Pearse, D. E., C. M. Eckerman, F. J. Janzen, and J. C. Avise. 2001. A genetic analogue of 'mark–recapture' methods for estimating population size: an approach based on molecular parentage assessments. *Molecular Ecology* 10:2711–2718.

Puget Sound Indian Tribes and Washington Department of Fish and Wildlife. 2010. *Comprehensive Management Plan for Puget Sound Chinook: Harvest Management Component*. April 12.

Rawding, D. J., C. S. Sharpe, and S. M. Blankenship. 2014. Genetic-Based Estimates of Adult Chinook Salmon Spawner Abundance from Carcass Surveys and Juvenile Out-Migrant Traps. *Transactions of the American Fisheries Society* 143(1):55–67.

Quinn, T. P. 2005. Comment: Sperm Competition in Salmon Hatcheries-The Need to Institutionalize Genetically Benign Spawning Protocols. *Transactions of the American Fisheries Society* 134(6):1490–1494.

Rawson, K., and M. Crewson. 2017. Snohomish Chinook Recovery Plan: Phases of Recovery and Integrated Adaptive Management Strategy Draft. Tulalip Tribes Natural Resources Department. Tulalip Tribes, Marysville, WA. 41p. May.

Ruckelshaus, M. H., K. Currens, R. Fuerstenberg, W. Graeber, K. Rawson, N. J. Sands, and K. J. Scott. 2002. Planning Ranges and Preliminary Guidelines for the Delisting and Recovery of the Puget Sound Chinook Salmon Evolutionarily Significant Unit. Puget Sound Technical Recovery Team.

Seber, G. A. F. 1982. The Estimation of Animal Abundance and Related Parameters, 2nd ed. Charles Griffin. London.

Simenstad, C. A., and J. R. Cordell. 2000. Ecological assessment criteria for restoring anadromous salmonid habitat in Pacific Northwest estuaries. *Ecological Engineering* 15(3):283–302.

Sokal, R. R., and F. J. Rohlf. 1981. Biometry: The Principles and Practice of Statistics in Biological Research. W.H. Freeman and Company. San Francisco, CA.

Tweit, B. 1986. Nisqually River Chinook Escapement Methods.

Volkhardt, G. C., S. L. Johnson, B. A. Miller, T. E. Nickelson, and D. E. Seiler. 2007. Rotary Screw Traps and Inclined Plane Screen Traps. Pp. 235–266 in D. H. Johnson (editors). Salmonid Field Protocols Handbook: Techniques for Assessing Status and Trends in Salmon and Trout Populations. American Fisheries Society. Bethesda, MD.

Wang, J. 2009. A new method for estimating effective population sizes from a single sample of multilocus genotypes. *Molecular Ecology* 18:2148–2164.

Waples, R. S. 1989. A generalized approach for estimating effective population size from temporal changes in allele frequency. *Genetics* 121:379–391.

Zimmerman, M. S., C. Kinsel, E. Beamer, E. J. Connor, and D. E. Pflug. 2015. Abundance, survival, and life history strategies of juvenile Chinook salmon in the Skagit River, Washington. *Transactions of the American Fisheries Society* 144:627–641.