NOAA Fisheries' Approach to Making Determinations Pursuant to the Endangered Species Act about the Effects of Harvest Actions on Listed Pacific Salmon and Steelhead

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Introduction

The purpose of this report is to describe the basis for determinations made pursuant to the Endangered Species Act (ESA) related to harvest actions that may affect listed Pacific salmon and steelhead. The report is organized into two sections. The first section provides an overview of the ESA-related consultation process. It also provides a more focused discussion that is specific to how NOAA Fisheries reviews harvest-related activities. The second section includes three case studies that were selected as examples to illustrate key points and the diversity of circumstances that must be addressed.

ESA Application

The form and substance of an ESA review is dictated by the statute and regulations. The ESA lays out very specific procedures and has its own jargon which in combination can be confusing and frustrating for those who simply want to get to the point - in this case the basis for harvest-related determinations. The purpose of this report is to provide an understandable review of NOAA Fisheries' approach to harvest decisions under the ESA. In this section we start with an overview of the section 7 consultation process. In the following discussion of harvest actions and case studies we minimize the use of jargon and process detail and focus on the key information used in jeopardy determinations related to harvest activities.

The effect of actions on listed species are reviewed through sections 7, 10, or 4(d) of the ESA depending on the nature of the action and who is proposing to take the action. The review process differs in detail depending on the section used for the analysis, but in all cases the ESA requires that NOAA Fisheries determine whether a proposed action, "... is likely to jeopardize the continued existence of a listed species or result in the destruction or adverse modification of critical habitat." As a result, NOAA Fisheries applies the same standards regardless of the review process. Because most harvest actions have been reviewed under section 7, this report uses section 7 as the model to explain how actions are reviewed and how standards are applied.

Before proceeding it will be useful to clarify the distinction between a "jeopardy determination" and a "consultation standard." A jeopardy determination is the result of a section 7 consultation. If a Federal agency proposes a fishery it initiates a section 7 review by providing a biological assessment. At the end of the consultation NOAA Fisheries determines whether the anticipated level of take will jeopardize the species or not - the jeopardy determination. Alternatively, NOAA Fisheries sometimes anticipates that a fishery will be proposed and provides guidance to the action agency to facilitate the consultation process in the form of a consultation standard which is a level of take that NOAA Fisheries believes will satisfy the no jeopardy requirement. If the action agency proposes a fishery that is consistent with the consultation standard, it can reasonably expect a no jeopardy conclusion. These consultation standards usually develop over time as a result of prior consultation on the same fishery. Considerations used for jeopardy determinations and consultation standards are the same.

Section 7 Consultation Overview

Section 7 of the ESA requires that all Federal agencies consult with NOAA Fisheries (or the US Fish and Wildlife Service regarding species listed under their jurisdiction) concerning the effects of their proposed actions on any species listed as threatened or endangered. Through this consultation process, section 7 may authorize Federal agency actions that may involve some "take" of listed species provided that such take is incidental to, and not the primary purpose of, the proposed action, and provided that the effects of the proposed action do not jeopardize the continued existence of the species or destroy or adversely modify designated critical habitat. ("Take" means to harass, harm, pursue, hunt, shooed, wound, kill, trap capture, or collect, or to attempt to engage in any such conduct (section 3(18) ESA).) The consultation process includes the documentation of a cause and effect analysis using best available scientific information in a biological opinion.

Section 7 Analysis

If an action results in take of listed species or adverse modification of critical habitat, a section 7 analysis is included in a biological opinion. Biological opinions determine the effects of a proposed action (hatchery program, harvest, dredging, permit issuance, etc.) on species likely to be adversely affected and on any designated critical habitat. The opinion analysis proceeds using the following outline:

1. Description of the proposed action and action area, including identification of the Federal agency and associated parties, purpose and timing of the action, statutory authority for the action, duration and location of the action, and the interrelated and interdependent actions. The action area defines the boundaries that include the direct and indirect physical, chemical and biotic effects of the action.

2. Identification of the species and critical habitat likely to be adversely affected, including a summary of the status, trends and population dynamics of the species, and condition of constituent elements of designated critical habitat. In the Northwest Region, NOAA Fisheries has developed guidance for analyzing the status of populations in a "Viable Salmonid Populations" paper (VSP). See McElhany et al. 2000 – the VSP paper. Viability requires adequate: abundance, productivity, spatial structure, life-history diversity.

3. Summary of the environmental baseline in the action area, including a review of past and present impacts of Federal, state, local and private actions (harvest, hydropower, habitat modifications, etc.) on the affected listed species and their habitat, any recovery activities, whether the environmental baseline is meeting the species' biological requirements, or whether improvement is needed. This is a species' level review. Steps two and three are designed to provide necessary context for the subsequent analysis of the effects of the action described below in step 4.

4. Analysis of the direct and indirect effects of the proposed and interrelated and interdependent actions, with cumulative effects (future actions) in a separate section.

Using best available scientific information NOAA Fisheries must determine whether the proposed action will jeopardize the continued existence of the listed species in the wild. NOAA Fisheries/FWS' regulations define jeopardy as follows:

> to engage in an action that reasonable would be expected, directly or indirectly to reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of the species.

Survival is a species' persistence with sufficient resilience to allow recovery. Recovery is improvement to the status of the listed species to the point at which listing is no longer required. (section 7 Handbook)

The steps in framing a jeopardy analysis are;

a. Identify all the direct, indirect and cumulative effects of the proposed action – either on individual members of the species or on the physical, chemical or biotic environment of members of the species. For certain types of actions, effects are well understood and evidence is readily available (e.g., hatchery effects on water quality, harvest effects on numbers or gear effects on fish, construction effects on water quality). For other actions, effects are not as well understood, particularly certain habitat modifying actions. Examples of questions NOAA Fisheries asks: Will action-area biological requirements be met if proposed action occurs? Will species-level biological requirements be met when proposed action is implemented along with other actions likely to occur?

b. Determine if any effects can be expected to reduce the reproduction, numbers or distribution of listed species. Then, determine if any such reductions will have the effect of reducing a species' likelihood of surviving and recovering in the wild given the current status of the species.

c. If, based on all relevant evidence NOAA Fisheries determines that the physical, chemical or biotic effects will not reduce a species reproduction, numbers or distribution then it will reach a no jeopardy conclusion. If, on the other hand, the analysis demonstrates that the action will reduce a species' reproduction, numbers or distribution – then the next question is: would those reductions reduce the species' likelihood of surviving and recovering in the wild, and whether this reduction will be "appreciable" (measurable). This can be the most difficult part of the analysis, but there are various ways to develop the evidence needed to support a conclusion. These require the use of best available information and are quantitative when possible, and qualitative when necessary.

5. Determine one of four possible outcomes: Likely to jeopardize, not likely to jeopardize, likely to destroy or adversely modify designated critical habitat, not likely to destroy or

adversely modify designated critical habitat. If the conclusion is no jeopardy/no adverse modification, then an incidental take statement is issued authorizing any incidental take and imposing reasonable and prudent measures (with terms and conditions) to minimize the take. If the conclusion is jeopardy then reasonable and prudent alternatives (if there are any) to the action are issued. However, the range of possible reasonable and prudent alternatives is subject to certain constraints. A reasonable and prudent alternative must be consistent with a no jeopardy determination. It must also be consistent with the original purpose of the action. If a proposed fishery receives a jeopardy determination, simply closing the fishery would generally not be an acceptable reasonable and prudent alternative. A closure would meet the no jeopardy requirement, but would likely not be consistent with the original purpose of the action. The ESA does not require that actions have no affect on listed species. It allows for "take", but requires that actions avoid jeopardy as defined above. Similar processes apply to adverse modification determinations regarding critical habitat.

Section 7 As Applied to Harvest Actions

For some types of actions the potential effects on the critical habitat of listed species are key. For salmon harvest actions the effects on critical habitat features are minimal. Hook-and-line gear and surface oriented nets used in most salmon fisheries have little or no effect on the environment. The analysis of harvest actions therefore typically focuses on the incidental mortality to maturing or adult listed fish that occurs as a result of fisheries directed at otherwise harvestable fish. For simplicity the following discussion leaves out details related to its consideration of critical habitat which is nonetheless included in every ESA review.

The Proposed Action and Affected ESUs

The first step in the analysis is to describe the proposed fishery and action area. This usually includes a description of the gears and methods used, and when and where the fishery will occur. Also included will be one or more management objectives that will define the level of expected catch. Management objectives generally include both conservation objectives (e.g., escapement goals or exploitation rate limits), and allocation objectives (how the catch will be shared among the various users). A fishery proposal may be local in scale such as a state and tribal fishery in the South Fork Salmon River below a hatchery weir, or more programmatic covering annual regulations for fisheries off the Washington, Oregon, and California coast managed by the Pacific Fishery Management Council (PFMC). The proposal may also be a plan for managing fisheries for a particular Evolutionarily Significant Units (ESU). The case study for Upper Willamette River Chinook provides an example of an ESU specific management plan. The action area is generally defined by the bounds of fishing activity.

The next step is to consider which of the listed ESU are likely to be affected by the fishery. This is a relatively straightforward determination based on the timing and distribution of the listed species. A fishery in the South Fork Salmon River may affect one population in the Snake River spring/summer Chinook ESU. Alternatively, PFMC fisheries affect three listed coho ESUs and seven listed Chinook ESUs.

A review of the status of each of the affected ESUs follows. This is an important and substantive step in the analysis. During this step the analysis focuses primarily on information about freshwater phases of the life history since this is where we are best able to observe the distribution and abundance of salmon and steelhead. The status review considers information on the population structure of the ESU, and to the degree possible, the status of each population within the ESU.

The status review generally begins with a comparison of the historic and present-day distributions of the ESU. The distributions of most of ESUs have been substantially reduced due to habitat loss often related to dam development. Providing a historical perspective of what used to be is important, but the analysis focuses on the status of populations within the currently accessible habitat. For some populations most or all of the historic habitat is still accessible. For others, all or virtually all of the historic spawning and/or rearing habitat is now inaccessible and populations exist only to the extent that they are supported by hatcheries. Puget Sound Chinook on the Elwha River or spring Chinook populations in the Lower Columbia River Chinook ESU provide examples of this latter circumstance. Most populations fall within the continuum of circumstances regarding available habitat where distributions are reduced by varying degrees. The status and productivity of remaining habitat is also relevant and it too may be largely unaffected or severely compromised.

Analyzing the status of an ESU requires an understanding of its population structure. Some ESUs are composed of single populations (e.g., Snake River Fall Chinook); others have twenty or more populations (e.g., Puget Sound Chinook). Technical Review Teams (TRT) have been established by NOAA Fisheries in recent years to assist with recovery planning. One of the first tasks of the TRTs is to determine the population structure of each ESU. NOAA Fisheries has relied on TRT recommendations regarding population structure as it becomes available or has relied on its own preliminary determinations when necessary based on best available information.

The analysis then reviews the status of each population relying on criteria developed by NOAA Fisheries and reported in its Viable Salmonid Populations (VSP) report (McElhany et al. 2000). The VSP report was designed to provide guidance for determining the conservation status of populations, and an explicit framework for identifying listed salmonid's biological requirements so that parties could assess the effects of management and conservation actions. The VSP report recommends evaluating the status of populations based on information related to 1) abundance, 2) trends and productivity, 3) spatial structure, and 4) diversity. During our review of population status the analysis tends to focus most on information related to abundance, and trends and productivity as these are most easily quantified. Reviews of the other two criteria tend to be more qualitative, but are nonetheless considered. With respect to the abundance criterion, the VSP report provides guidelines for developing "viable" and "critical" abundance levels to serve as benchmarks for assessing the status of populations. Comparison of abundance estimates and trends in abundance relative to the viable and critical criteria give important perspective regarding the status of the populations.

Environmental Baseline and Cumulative Effects

The environmental baseline includes a review of past and ongoing human and natural factors leading to the current status of the species. The purpose is to provide a snapshot of a species' health at present and thus provide context for analyzing the proposed action. Providing a concise and comprehensive summary of the environmental baseline can be difficult because of its complexity. For salmonids past actions contributing to a species decline are usually many and characterized only qualitatively in terms of impact or relative importance. The range of ongoing activities and their consequences is likewise complex. The changing status of natural factors is relevant to the baseline discussion. We are increasingly aware of the importance of natural events on salmonid populations (e.g., long-term oceanographic cycles, El Ninos, or droughts). A question that helps focus the discussion of the environmental baseline is whether the species' biological requirements are currently being met. Information of the species' status described above provide an important indicator. If a species' abundance has continued to decline, its biological requirements are likely not being met.

Cumulative Effects has a specialized meaning in an ESA section 7 analysis that is quite narrow and different than what is generally understood in different contexts such as NEPA. A section 7 cumulative effects analysis is limited to the effects of *future non-federal actions that are reasonably certain to occur in the action area*. Future actions are obviously critical to a species' future status, but in practice in the context of past harvest consultations, it has been difficult to identify actions that are "reasonably likely to occur" and even more difficult to say with confidence how those activities will affect the species either positively or negatively. As a result, the cumulative effects section of most harvest biological opinions commonly has relatively little that is substantive or critical to the analysis or conclusion.

Effects of the Action and Jeopardy Determination

The above described elements of a section 7 review are all designed to provide the necessary context for analyzing the effects of a proposed fishery and making a determination with respect to jeopardy. The following section deals with the anticipated effects of the fishery and the determination itself. The associated analysis generally involves three steps: 1) quantify the effects of the fishery, 2) assess the impacts on the component populations, and 3) integrate all of the available information to make the final determination.

The first step is to quantify the effects of the fishery in terms of the number of fish expected to be killed, often expressed in terms of an exploitation or harvest rate. These assessments seek to estimate *total* anticipated mortality associated with the fishery including landed catch and any additional mortality that may occur as a result of the fishery. For example, mortality estimates typically account for fish caught and kept, undersized fish that are caught and released, mortality to fish that encounter the gear but are not landed (dropoff mortality), and fish that are caught and released in selective fisheries that require the release of unmarked fish for example or non-target species (e.g., coho released in a Chinook-only fishery). The goal is to account for all of the direct and indirect effects of a fishery.

The second step in the analysis is to consider, to the degree possible, the effect on each population in each ESU. As indicated above the timing and location of a proposed fishery may be such that the number of affected ESUs and populations is limited. The case study on Upper Willamette River spring Chinook, for example, focuses on a proposed harvest management plan for Willamette spring Chinook. As a result, the review is limited to the effects on three existing populations in this one ESU. In other cases, proposed fisheries may affect several ESUs, each of which have one or more population. Criteria outlined in the VSP paper described above provide a consistent framework for characterizing the status of the populations and discussing the anticipated effects.

NOAA Fisheries analyzes the effects on populations using quantitative analyses where possible and more qualitative considerations where necessary. We have several examples where fisheries have been analyzed using risk assessments and stochastic population models. These provide a quantitative framework for analyzing risk and considering the likelihood of survival and recovery given the proposed fisheries. Results from these assessments are used in conjunction with additional qualitative considerations when making related jeopardy determinations. Key examples include the use of Rebuilding Exploitation Rates (RERs) that have been developed and applied to date primarily for Puget Sound Chinook fisheries, and the risk assessments associated with the review of fisheries for Upper Willamette River spring Chinook and Oregon Coast coho. The first two of these examples are described in more detail in the case studies. The Cumulative Risk Initiative (CRI) provides another example of a quantitative analytical framework that has been used during the ESA review process. The CRI was developed in conjunction with the section 7 consultation on the Federal Columbia River Power System (FCRPS). The CRI has been applied to date only to the Columbia Basin ESUs. It provides a consistent framework for analyzing extinction risk based on abundance trends observed over a specified time period. In the 2000 FCRPS opinion, for example, the CRI analysis generally relied on abundance estimates observed from 1980 through 1999.

The quantity and quality of information for the 26 listed salmonid ESUs varies widely. There are data-rich circumstances that lend themselves to the kinds of quantitative risk assessments described above. In other cases the information necessary to do quantitative risk assessments is simply not available. The winter-run case study provides an example of a data poor circumstance. Absent such information, determinations depend more on qualitative considerations including those described below:

1. <u>Most recent information of population abundance and trends:</u> This includes current year forecasts, recent trends, and survival rate indicators. Has abundance continued to decline or is there evidence that circumstances have changed? How does the current abundance compare to critical and viable abundance levels developed per VSP recommendations?

2. <u>Level of harvest reductions relative to the period of decline:</u> Most populations within listed ESUs have undergone a prolonged period of decline. In order to halt the decline and begin recovery, mortality needs to be reduced. Although in may not be clear how much of a reductions is required, it is reasonable to expect that harvest will be reduced compared to levels observed during the period of decline.

3. Absolute magnitude of harvest impacts: In some cases harvest impacts have long since been reduced to low levels so the opportunity to achieve further survival improvements is limited. Expectations for further reductions differ, for example, for populations that have been subject to harvest rates of 10% or less compared to populations that have been subject to harvest rates of 50% - 70% prior to ESA review.

4. Remedial actions taken in other sectors: In some cases it is clear that other activities have been substantially responsible for a populations' decline. If those actions have been identified and fixed with reasonable certainty, then requirements for further reductions on harvest will be reduced. The winter-run case study provides a relevant example.

5. Availability of draft recovery plans: The Proposed Recovery Plan for Snake River Salmon (1995) and the subsequent All-H Paper (2000) were not final recovery plans, but nonetheless provided guidance regarding how the burden of conservation should be shared among the various sectors and, in particular, how harvest should be managed in the near term in a broader context than is otherwise available. Compliance with these more comprehensive recovery plans, when available, is an important consideration.

6. Existence of hatchery supplementation programs: Hatchery supplementation programs, if properly managed, reduce the risk of near term extinction. For populations, or ESUs consisting of a single populations, associated supplementation programs reduce the risk of catastrophic failure by providing a second brood source and can be used to accelerate recovery by more rapidly increasing abundance. Hatchery programs may also have adverse long-term effects depending on how the program is managed which must also be accounted for. For Snake River fall Chinook and Sacramento River winter-run Chinook the existence of conservation-based hatchery programs have been considered as a positive mitigating factor in the related determinations.

7. Healthy populations within an ESU: Although most populations within listed ESUs are depressed, some populations are healthy. Lewis River fall Chinook in the Lower Columbia River Chinook ESU is an example. Escapement of natural-origin fish to the Lewis has exceeded the escapement goal of 5,700 in every year but one for at least the last twenty years with little or no influence from hatchery-origin fish. Under these circumstances additional ESA-related harvest management constraints are generally not considered necessary. Other more depressed populations are subject to harvest constraints and therefore provide indirect protection for healthy populations by holding down harvest impacts in mixed stock fisheries.

8. Populations with no spawning habitat supported by hatchery programs: In some cases the spawning habitat of populations is no longer accessible due to hydro development and the genetic resource of the populations exists only as a result of a hatchery program. The hatchery population is important because of the possibility of opening up currently inaccessible habitat. In these cases, harvest programs are regulated for the time being to

meet the escapement needs of the hatchery program. Elwha River Chinook from the Puget Sound Chinook ESU and spring Chinook populations in the Lower Columbia River Chinook ESU provide examples.

9. <u>Duration and scope of the proposed action:</u> NOAA Fisheries takes into account the duration and scope of the proposed action in determining the allowable risk. The greater complexity of longer duration and broader scope actions generally have a greater degree of uncertainty than shorter term, more site specific actions and thus may require more rigorous analysis and potentially a more conservative level of allowable risk. They certainly require greater reliance on monitoring and adaptive management. On the other hand, broad scale actions account for a greater proportion of the total mortality.

None of these qualitative considerations are definitive by themselves, but all have been used in various combinations during past harvest related determinations.

The final step in a section 7 review is the jeopardy determination itself. This is the step where all of the above described information must be integrated to determine whether the proposed fishery will "... reduce appreciably the likelihood of both the survival and recovery of a listed species ..." There are several additional points that frame the context for these final determinations.

It is relevant to clarify that the jeopardy determination is made at the level of the species or ESU and not individual populations. Where an ESU has only one population the distinction is trivial. However, for ESUs composed of many populations it is not necessary that all populations have a similar high probability of recovery to avoid jeopardy. An ESU may be considered healthy and recovered if most of the populations are recovered, and the geographic and life history diversity of the ESU is adequately represented. The TRTs are, for example, developing criteria that may be used for describing these sorts of alternative recovery scenarios. Although it may be appropriate to consider varying risk levels for individual populations within an ESU in a jeopardy determination, it would be inappropriate to presume a specific outcome in a near-term consultation that would preclude the recovery of any particular population before the recovery scenario is decided through recovery planning.

Ultimately how much harvest can be allowed depends on the capacity and productivity of the freshwater habitat, ocean survival rates, the magnitude of human induced mortality which reduces production, and policy decisions about how the burden of conservation will be shared among the various factors of decline. The Salmon Recovery Science Review Panel also noted that: "There is no simple answer, since there are likely to be multiple feasible paths leading to the same goal. Improvements in the stock abundances can be achieved through a variety of actions, and the choices among these will involve not only science, but also socio-political decisions." (SRSRP 2001) Finding the appropriate balance is a problem with multiple solutions. The necessary long-term decisions will be made through recovery planning. Although recovery planning is underway and a priority for the region, there are currently no final recovery plans for any of the listed ESUs. Until recovery plans are completed, jeopardy determinations for harvest actions, or any action for that matter, are necessarily interim in nature. As a result, there is currently uncertainty about what sort of long-term harvest plan is appropriate.

Recovery plans will presumably provide guidance on how the burden of conservation will be distributed including the level of harvest that should be included as part of the mix. In theory recovery plans could embrace a solution that allows for little or no harvest and thereby reduce the requirements on other sectors. Policy decisions relative to recovery planning are not final, but there is nonetheless clear policy that anticipates that harvest will be part of the solution set, particularly as it relates to tribal fisheries. The policy commitment to tribal harvest is articulated succinctly, for example in a letter from the former NOAA Deputy Administrator (Garcia 1998)[1], and in more detail in the Columbia Basin-Wide Salmon Recovery Strategy, also known as the All-H Paper (Federal Caucus 2000)[2]. Absent recovery plans, we cannot be specific about the level of harvest, but policy has developed to the point where it is appropriate to presume that the solution set will be constrained to include some level of harvest. This policy direction therefore reduces the uncertainty to some degree.

Jeopardy determinations related to harvest must be responsive to current information on species status and the environmental baseline, and future information on species status and developing policy. The context for these determinations is always one of uncertainty. The solution used in response to this uncertainty is to adopt an adaptive approach to harvest management and the related determinations. In the context of our harvest consultations this means making decisions based on the best available information, while at the same time being mindful of the need for close monitoring of outcomes and the ability to change direction in response to new information.

Current harvest consultations seek interim solutions based on the requirement that they be consistent with expectation of survival and recovery and best available information. Harvest actions are well suited to adaptive management for two reasons. First, unlike most other activities, impacts of harvest actions are well understood and estimated with relative accuracy. For example, fisheries are typically managed to a specific total mortality limit. Second, harvest actions can be adjusted between years in response to evolving information on a species' status. The duration of harvest consultations are generally short-term (1 year or a few years at most). Where we have longer-term consultations, decisions are always provisional since jeopardy determinations must be reviewed (by regulation) based on new information that is relevant to an existing determination. Contrast this to habitat activities (e.g., a 50-year Habitat Conservation Plan or forest management policy) where impacts are only qualitatively understood and will persist for decades. With harvest actions an initial determination can be continuously reviewed and adjusted immediately if necessary if a species status does not improve as expected. The

[1]For example, the Garcia letter says, "... The tribes may reasonably expect, as a matter of policy, that tribal fishing rights will be given priority over the interests of other entities, federal and non-federal, that do not stand in a trust relationship with the United States."

[2]One of seven program goals from the Basin-wide Salmon Recovery Strategy: Assure Tribal Fishing Rights and Provide Non-Tribal Fishing Opportunities. Restore salmon and steelhead populations over time to a level that provides a sustainable harvest sufficient to allow for the meaningful exercise of tribal fishing rights and, where possible, provide non-tribal fishing opportunity.

winter run case study provides an example where more restrictive harvest measures were implemented as a result of a subsequent review when the species status failed to improve as expected after an initial determination.

Summary

The purpose of this report is to describe how NOAA Fisheries makes harvest management decisions within the broader context of the ESA and other applicable laws and policies. NOAA Fisheries may analyze proposed fisheries under section 7, 10, or 4(d) of the ESA, depending on who is proposing the fishery and how they choose to present it for review. However, the key features of an ESA analysis are the same regardless of the section of the ESA that is applied.

The form and substance of an ESA review is dictated by statute and regulation. The resulting review process and associated jargon are important since they must be adhered to, but can also be confusing because of their complexity. In this report, we provide an overview of the section 7 ESA review structure as an example, but in the more detailed discussion and case studies minimize the use of jargon and process-related detail, and focus instead on the substantive elements of the analysis.

A key to NOAA Fisheries' harvest-related decisions is their reliance on adaptive management. Harvest is different from many other types of actions (e.g., habitat actions) in that harvest impacts are comparatively well understood and decisions can be reviewed annually and adjusted as necessary. Harvest decisions must be made based on available information and on an expectation that allowable harvest impacts are consistent with future survival and recovery. However, if the status of stocks does not improve as expected, additional actions can be taken in subsequent years. Harvest decisions are responsive to evolving science and related policy direction regarding, for example, population structure of ESUs, recovery levels for each population, or recovery plans that will eventually provide more specific guidance about risk and the balance of survival improvements expected from each sector. Harvest is also responsive to increasing reliance on more quantitative information as risk assessments are developed, refined, and applied.

Finally this report seeks to clarify the role of policy consideration in the decision process. Policy input is necessary and appropriate, for example, in deciding on what level of risk to accept or the relative balance between various mortality sectors. While it is important to recognize that ESA decisions require biological and policy input, it is also important that the distinction between the two remain clear.

The first section of this report provided an overview of the ESA-related consultation process. The second section includes three case studies that were selected as examples to illustrate the key points discussed above and the diversity of circumstances that must be addressed.

The first case study on Sacramento winter-run Chinook considers an ESU with a single extant population. It provides an example where the data was initially very limited, although it has improved since the ESU's was first harvest-related consultation in 1991. The case study also provides an example where harvest was reduced because of the depressed status of the ESU, but policy direction relied for remedial action primarily on improvements in other sectors thought to be directly responsible for the species decline. In the last several years the status of the ESU has improved dramatically.

The second case study considers Upper Willamette River Chinook. This is still a relatively simple ESU with three extant populations. Reforms have been implemented to address hatchery production programs that were identified as a factor of decline including marking of all released hatchery fish. Harvest impacts were substantially reduced through implementation of a mark-selective fishery in all freshwater fishing areas. In this case, the data was better and allowed greater reliance on a quantitative risk assessment of the proposed management program.

The third case study considers a harvest management plan for Puget Sound Chinook. Puget Sound Chinook are one of the most complex ESUs with 20 or more populations. The case study describes a risk assessment tool that was developed specifically for analyzing Puget Sound Chinook populations and the proposed harvest plan. The case study describes how the risk assessment is applied where possible, combined with more qualitative considerations for other populations, to make the ESA determination in a more complex management scenario.

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CASE STUDY 1
SACRAMENTO RIVER WINTER-RUN CHINOOK

Overview
NOAA Fisheries considered the effect of ocean salmon fisheries off the coast of Washington, Oregon and California on Sacramento River winter-run chinook through a sequence of ESA consultations. NOAA Fisheries completed its first consultation in 1991. Consultation standards were subsequently modified (in 1996, 1997, and 2002) in response to evolving information related to the species' status, harvest impacts, and habitat conditions. This review of winter-run harvest consultations provides an example of how NOAA Fisheries has used short-term consultations and an adaptive approach to respond to circumstances where available information was initially very limited and evolving over time.

To understand the basis of NOAA Fisheries' harvest-related decisions on winter-run chinook it is necessary to understand what was known at each decision point. This case study is therefore organized to first review information related to key subject areas. After briefly describing the proposed fishery, the case study describes: 1) information related to the distribution of the Sacramento River Winter-run chinook ESU; 2) population abundance and trends; 3) habitat conditions and related remedial actions; and 4) ocean distribution and harvest impacts. The sequence of harvest consultations are then discussed in turn.

Proposed Action/Fishery Plan
NOAA Fisheries considered ocean salmon fisheries that occur off the coast of Washington, Oregon, and California and the associated harvest impacts to winter-run chinook for ESA compliance. These fisheries are managed under the jurisdiction of the Pacific Fishery Management Council (PFMC or Council). Chinook and coho salmon are caught in commercial and treaty Indian troll fisheries, and recreational hook-and-line fisheries. Fisheries are regulated using quotas, time and area controls, size and species-retention limits, and gear requirements. Regulations are adjusted annually to meet stock-specific conservation requirements specified in the PFMC's Salmon Fishery Management Plan in addition to those for ESA listed species. The fisheries are also regulated to meet allocation objectives.

Winter-run chinook are distributed almost exclusively off the California coast. As a result, harvest-related regulatory actions for winter-run chinook have been limited to that area.

Distribution of Sacramento River Winter-run Chinook
Historically, winter-run chinook depended on access to spring-fed tributaries in the headwaters of the Sacramento River that stayed cool during the summer and early fall. Winter-run chinook were abundant in the McCloud, Pit, and Little Sacramento rivers which presumably comprised separate populations. Smaller populations may also have been present in Battle Creek and the Calaveras River (Figure 1 map).

The most obvious challenge to the survival of winter-run chinook was the construction of Shasta Dam located at RM 311 and completed in 1944. The dam was built without passage and blocked all or nearly all of the species' spawning habitat. Winter-run chinook were not expected to survive dam construction. Cold-water releases from Shasta Dam fortuitously created suitable spawning conditions for winter-run chinook in the mainstem Sacramento River below the dam. As a result, the species' distribution was relocated and the multiple population structure merged to form what is now a single population. If there ever were populations in Battle Creek and the Calaveras River, which are located below Shasta Dam, they are now extirpated.

Figure 1. Sacramento River Basin.

Keswick Dam (RM 302), located nine miles below Shasta Dam, was completed in 1949. No passage for salmon was provide at Keswick Dam either so it currently defines the upstream boundary for winter-run chinook. The distribution of spawners is limited by the availability of cool water. The primary spawning habitat of winter-run chinook currently extends from Keswick Dam downstream approximately 31 to the mouth of Battle Creek (RM 271). Redd surveys suggest that 90% of the spawning activity occurs in the uppermost 14 miles below Keswick Dam.

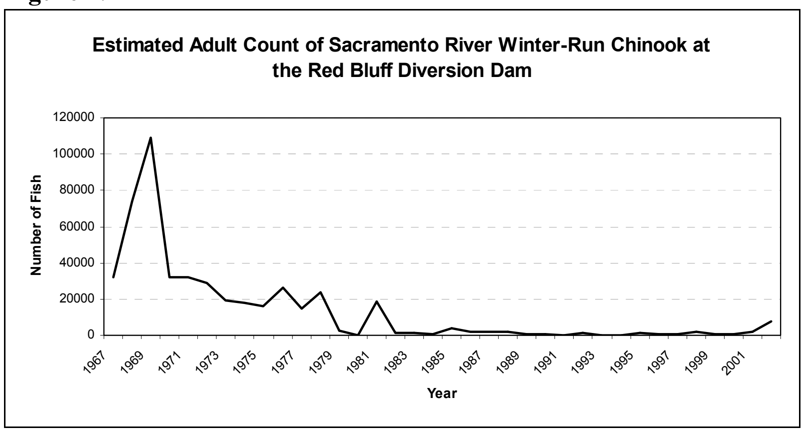
Population Abundance and Trends

There were no direct estimates of the abundance winter-run chinook until after Red Bluff Diversion Dam (RBDD) was completed in 1966. Information on the historic run size of winter-run chinook is vague, but indicates an annual return of 100,000 to 200,000 fish (NMFS 1991). NOAA Fisheries issued a draft recovery plan for winter-run chinook in 1997. The draft plan recommended a delisting goal of 10,000 female spawners per year averaged over 13 years. The recommended goal is subject to review by the recently appointed Technical Review Team, but for now provides a bench mark for assessing the status of winter-run chinook in the existing habitat.

The RBDD is located at RM 246 approximately 56 miles below Keswick Dam. Completion the dam's fishways enabled relatively accurate counts of the number of fish passing upstream. However, dam operation and passage conditions had a significant adverse impact on both juvenile and adult winter-run chinook. Beginning in 1989, NOAA Fisheries required operational changes that involved removing the dam gates for increasing periods to improve passage conditions. As a result, the estimate of winter-run chinook return was based on the observation of a decreasing portion of the run. By 1993 and thereafter, only the last 15% of the run was observed directly. Subsequent run size estimates were based on expansions of these partial counts using assumptions about average run timing from observations prior to 1989. Because the dam tended to delay adult passage, estimates from RBDD since 1989 are regarded as both imprecise and negatively biased.

Population estimates from the RBDD averaged over 50,000 during the first five years starting in 1967. The population declined to a low of just a few hundred fish by the early 1990s, but has since shown significant and sustained growth with an estimated run of over 7,600 adults in 2002 (Figure 2).

Figure 2.

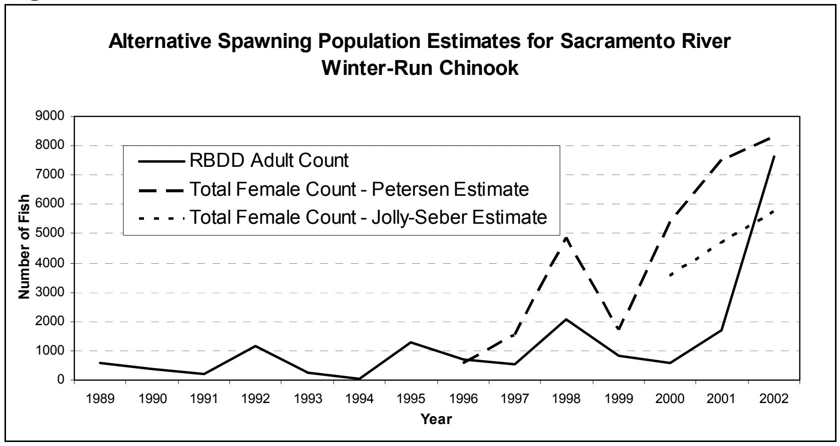


Because of the problems with the abundance estimates from RBDD, the California Department of Fish and Game (CDFG) began conducting carcass surveys on the winter-run chinook spawning grounds in 1996. Population estimates were developed using mark-recapture techniques. Unlike the fish counts at the RBDD, carcass surveys are conducted over the entire spawning season so the whole population is sampled. The Petersen model and, when possible, the Jolly-Seber model have been applied to the carcass sampling data to provide estimates of the spawning population. There is some concern that the Petersen estimates may have a positive bias. They nonetheless provide an alternative estimate and have been used in recent years to indicate the population trend.

There are other problems with the carcass surveys that have not been fully resolved. It is apparent that grilse are poorly sampled on the spawning grounds as there are generally far more counted at RBDD than estimated from the carcass survey. The recovery rate of females in the carcass surveys is also higher than that of males, apparently because the females tend to hold on the spawning grounds longer. Estimates of female spawners from the carcass surveys may therefore provide the most reliable indicator of abundance.

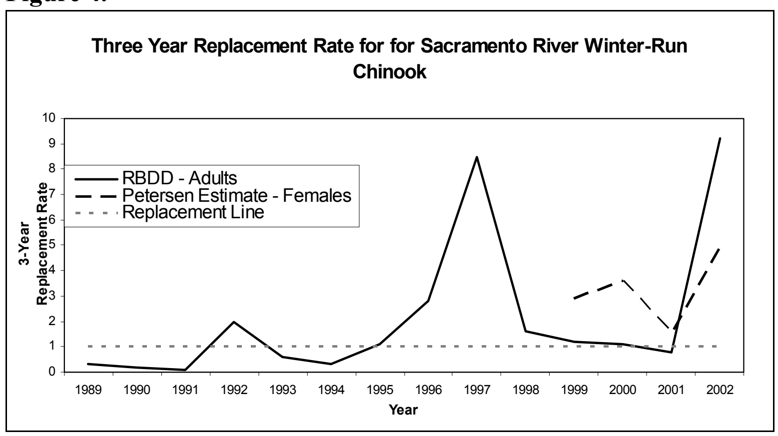
The Petersen estimates indicate that the number of female spawners has increased from approximately 600 in 1996 to over 8,300 in 2002. Estimates developed using the Jolly-Seber model tend to be somewhat lower, but show the same increasing trend (Figure 3).

Figure 3.



Adult replacement rates have been calculated and used through the successive consultations as an indicator of populations trends and rebuilding rates. Winter-run chinook have a relatively simple age structure with 89% of females returning at age 3. A 3-year replacement rate is calculated as the return of fish in year *n* divided by the return in year *n*-3. Replacement rate estimates from the RBDD counts indicate that the population began a sustained recovery beginning with the 1995 return year (1992 brood year). Replacement rates calculated from the Petersen estimates of female abundance averaged 3.2 for the 1996 - 1999 brood years indicating very rapid population growth in recent years (Figure 4).

Figure 4.



Habitat Conditions

The decline of winter-run chinook has been attributed to many causes. Shasta and Keswick dams dislocated winter-run chinook from their historic spawning grounds, but the population reestablished itself in the area below the dam. In 1989 when winter-run chinook were first listed the primary reasons identified for the species' decline were the operation of RBDD and other human activities that had degraded spawning and rearing habitat in the Sacramento River. The incidental take of winter-run chinook in fisheries was not identified as a primary contributing factor in the listing determination. Following completion of Shasta and Keswick dams in the 1940's, the population had reestablished itself with returns ranging from 30,000 to over 100,000 in the late 1960's despite ongoing fisheries.

It was apparent early on that several of these habitat factors were critical to the species' dramatic decline and that remedial actions were necessary to prevent extinction. Several such actions were undertaken in the late 1980s and early 1990s and were therefore beginning to take effect during the sequence of harvest consultations. Understanding the significance of these actions is therefore pertinent to NOAA Fisheries' review of its harvest consultations. (For a useful overview of actions affecting winter-run chinook and subsequent remedies see CSWC (2002)).

Identifying key habitat problems affecting listed species and providing timely and effective remedies is often a frustrating and time consuming process. The circumstances on the Columbia River where there are 12 listed ESUs distributed throughout the basin provides a case on point. By comparison, the circumstances for winter-run chinook were relatively simply; there was a single population confined to approximately 50 miles of main stem spawning habitat. High priority remedies that were identified included providing safe passage for juveniles and adults, and cool, clean water in the area below Keswick Dam.

Critical passage problems occurred as a result of RBDD and a host of other unscreened diversions that complicated adult passage and/or entrained juveniles during migration. RBDD severally limit both adult and juvenile passage. Fish ladders built during the original construction were only partially effective. Radio tagging studies indicated that 40% of adults failed to pass over the dam when the gates were operating which helps explain the species' precipitous decline. There was little successful spawning below the dam because of high water temperatures. An attempt was made to improve the ladders in 1984, but the benefits were marginal. It was not until operational changes were implemented beginning in 1989 that adult passage impediments were effectively addressed. By that time the population had declined to very low levels.

Juveniles were also significantly affected by RBDD in at least two ways. Juveniles were entrained in water diverted to the Tehama-Colusa Canal which is one of the largest diversions in the system with a capacity of 3,000 cfs. By-pass screens that minimized entrainment were completed in 1992. Juveniles were also subject to significant predation by pike minnows and striped bass at the screen bypass discharge. Operational changes that were phased in beginning in 1989 have substantially reduced these passage problems for juveniles.

Screening of other water diversions on the main stem Sacramento was identified as an additional high priority. System improvements were made at the Glenn Colusa (3,000 cfs capacity) and Anderson-Cottonwood Irrigation District (400 cfs capacity) weirs in 1992 and 1993, respectively to limit juvenile diversions. Since then an aggressive screening program has been implemented. All of the largest diversions in the system are now screened or have programs in progress and the priority has shifted to target the remaining smaller unscreened diversions.

Providing a cool and stable supply of water below Shasta Dam during spawning and incubation was also critical to the species' survival. The state implemented temperature related operation criteria beginning in 1975. More specific requirements were implemented in 1992 through NOAA Fisheries' biological opinion related to the operation of Shasta Dam. A large temperature control device was installed in 1997 which further improves capabilities to meet flow and temperature requirements even in dry years, thus reducing the risk of future failures in the water supply.

Acid drainage from Iron Mountain Mine was historically the largest source of pollution to the Sacramento River. Drainage from the mine contains high concentrations of copper, zinc, cadmium and other metals and produced chronically and occasionally acutely toxic conditions in the Sacramento River below Keswick Dam in the heart of winter-run chinook spawning habitat. Some remedial actions were taken as early as 1963, but uncontrolled spills still resulted in toxic conditions and fish kills. More effective action was taken beginning in 1989. From 1989 - 1993 emergency treatment actions minimized toxic releases. By 1994 more permanent remedies were implemented that have effectively removed the acid mine drainage as a source of mortality.

Other significant actions have also been taken to improve habitat conditions in the basin including CalFed's Ecosystem restoration program, spawning gravel replacement, and opening of new habitat on Battle Creek. These projects and others have been phased in since listing. It is difficult to calculate the benefit of individual actions or the collective improvement in survival for all of the actions. However, these were identified as key factors of decline for the species. There was therefore reason for optimism that winter-run chinook would respond positively as these remedies were phased in. Recent returns have substantiated those expectations.

Ocean Distribution and Harvest Impacts

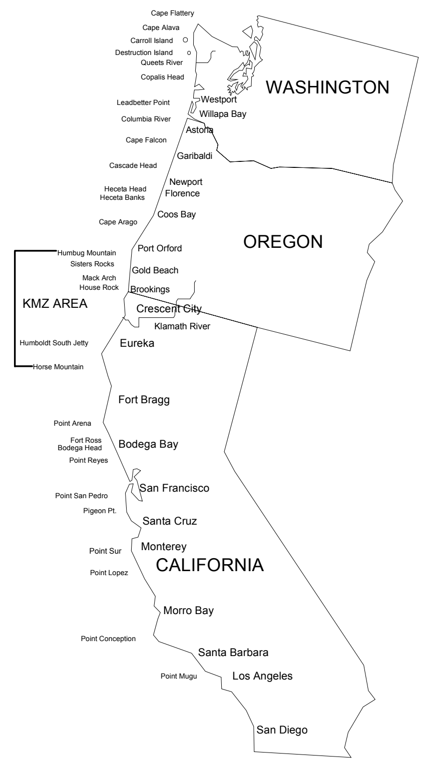
Information related to ocean distribution and harvest impacts on winter-run chinook has, until very recently, been quite limited. However, qualitative information about their life history indicates that winter-run chinook are subject to substantially less harvest than fall stocks in particular. Mature winter-run chinook exit the ocean from November to mid-May with the peak leaving in February and early March. The majority of the run passes RBDD at RM 246 between January and May with the peak in mid-March. Winter-run chinook also mature primarily at age three (89% for females). As a result, they are vulnerable to the bulk of ocean fisheries that target fall stocks during the spring and summer months only as immature fish and for one season prior to entry into freshwater. Maturing fish are also relatively small so gain further protection from size limit regulations.

Until the mid-90s the only direct information available on ocean distribution and harvest impacts was from studies using fin-clipped fish from the 1969 to 1971 brood years. The study used 720,000 wild winter-run chinook juveniles which were collected at RBDD in 1969, 1970, and 1971, marked with a fin clip and released. Marked fish were recovered in ocean fisheries and at RBDD. Although there were significant shortcomings related to the studies (Interagency Workgroup 2003), the available information indicated that catch/(catch + escapement) ranged from 0.47 to 0.56[1].

[1]Harvest rate is generally expressed as the fraction of fish available to the fishery that are landed by a fishery. The catch/(catch + escapement) value, when calculated using the ocean and inriver recoveries from all year classes of a brood, is an approximation of harvest rate that does not take into consideration the fraction of the population removed by natural mortality. The catch/(catch + escapement) value therefore overestimates the true harvest rate on a population.

The fin clip study also provided information on the distribution of harvest in the ocean. The results of the study indicated that 78% of the impacts occurred in the recreational fishery and 22% in the commercial. The majority of impacts occurred in areas south on Point Arena. Cumulative information from subsequent CWT releases confirm the earlier conclusions regarding distribution. Of the CWT-marked fish recovered from ocean fisheries between 1993 and 2001, 95% were landed south of Point Arena. Of those, 62% were landed south of Pigeon Point (Figure 5).

Figure 5.



The fin clip data was used to develop the Winter-run Chinook Ocean Harvest Model (WCOHM) that was relied on beginning with the 1996 consultation. There was, and still is, insufficient information to predict ocean abundance or escapement preseason. The model was therefore used to estimate the relative change in harvest impact compared to a set of base years. The model uses a synthetic population reconstructed from the marked winter-run chinook broods of 1969 and 1970. Fishery impacts and escapement are projected for this population under alternative fishery regimes, and compared with those impacts and escapement expected under baseline conditions. Baseline conditions are a composite of the 1971 - 1973 fishing seasons and effort. Because fishing seasons and regulations were relatively stable from the early 1970s through late 1980s, it is assumed that these baseline conditions are also indicative of fishery conditions just prior to listing. The model stratified the fishery into California waters north and south of Point Arena, commercial and recreational fisheries, with monthly time increments. Reductions in effort relative to that observed during the base years were presumed to represent proportional reductions in harvest impact.

The next available estimates of ocean distribution and harvest impact came from groups of fish marked with coded wire tags (CWT) and released from the Colman National Fish Hatchery located on Battle Creek. The data was again quite limited. The number of marked fish released for the 1992 and 1993 brood years was 23,000 and 17,000 fish, respectively. (The usual size of a release group for a harvest indicator stock is 200,000.) The number of observed tags recovered from the fisheries was 17 and 5 for the respective brood years. Estimates of catch/(catch + escapement) were 0.54 for the 1992 brood and 0.19 for the 1993 brood year. The weighted two-year average was 0.40. The results were therefore mixed. One estimate indicated that harvest impacts were still comparable to those of the early 70's developed using the fin clip data; the other that harvest impacts were much reduced. The winter-run chinook program at the Coleman Hatchery was discontinued after the 1996 brood releases because of operational problems. Fish released from Colman Hatchery in the upper basin continued to return to Battle Creek which has no spawning habitat rather than the upper Sacramento River as intended. There was also some indication that winter and spring-run brood stocks were being mixed.

Because of the problems at the Coleman Hatchery, an alternative production site was built. The Livingston Stone Hatchery National Fish Hatchery was constructed in 1997 at the upper end of the basin near Keswick Dam. Releases from the Livingston Hatchery provided, for the first time, sufficient information to conduct a cohort analysis and thereby estimate the number of fish recruiting to the fishery and an ocean age-3 harvest rate. The estimated harvest rate for the 1998 brood year was 0.23. A preliminary estimate for the 1999 brood year was 0.22.

Livingston Stone Hatchery was designed as a conservation hatchery with the sole purpose of helping to restore the natural production of winter-run chinook. All production is marked with an adipose fin clip. Every individual used in the program is genotyped to confirm that it is a winter-run chinook. No more than 10% of the broodstock is from hatchery-origin fish and no more than 15% of the returning wild run is taken for broodstock, with a maximum of 120 fish taken per year. These steps are taken to minimize the potential adverse effects associated with hatchery operations for the supplementation program.

Sequence of Harvest Consultations

<u>1991 Biological Opinion</u>

Winter-run chinook was the first salmon species listed under the ESA. The effect of ocean salmon fisheries on a salmon species was considered for the first time in the 1991 biological opinion (NMFS 1991). The available information was limited. The conclusion and associated rationale were therefore qualitative.

The primary considerations in the opinion were that ocean impact rates were relatively low, and that remedial actions had been taken in other sectors that provided the necessary protection. Run timing information indicated that most maturing fish existed the ocean by February or early March. Unlike fall stocks that were targeted in the ocean fishery, the age-at-maturity was such that winter-run fish were generally subject to only a single year of harvest. Size limits further reduced likely impacts particularly in the commercial fishery. The only information available for estimating ocean harvest mortality was the fin-clip study data from conducted in the early 1970's. This was used to calculate a catch-to-escapement ratio of 0.53:1 which was considered "low" relative to other west coast stocks. For perspective this was compared in the opinion to similar estimates of between 1:1 to 2:1 for Washington coastal stocks and 4:1 for fall stocks off of California. Results from the fin-clip analysis therefore supported the qualitative conclusions, based on the life history data, that the harvest impacts were low. However, there was insufficient information to quantify what "low" meant in terms of an exploitation rate or other measure of absolute mortality.

At the time of listing, the causes of the population's precipitous decline were reasonably well understood: passage problems at Red Bluff Diversion Dam, entrainment of juveniles by numerous unscreened diversions, and lethal temperatures in the Sacramento River exacerbated by drought conditions. Estimates of adult passage mortality at RBDD alone were 40%. At the time of listing, harvest was not considered as a primary factor for the species decline. NOAA Fisheries' recovery actions for winter-run chinook were therefore directed almost entirely at improving spawning and migration habitats in the Sacramento River and Delta. A judgment was made at the time of the opinion that actions had been taken to address the principal sources of mortality and that those actions would be sufficient to begin the process of recovery. Actions taken to reduce harvest were therefore relatively modest. The opinion required that future fisheries not exceed those observed in 1990. The recreational season south of Point Arena, which traditionally ran from February 15 through November 15, was shortened by two weeks at both ends of the season to provide more opportunity for maturing fish to exit the ocean. The state of California also implemented a conservation control zone that closed the fishery outside of Golden Gate from November 1 through April 30. A proposal for an early opening (prior to May 1) of the commercial fishery south of Point Arena was also disallowed.

It was not possible at the time to quantify the effect of these changes in harvest management or the benefits of ongoing habitat actions. However, the opportunity for reconsidering the available information and reinitiating consultation if necessary remained. With this in mind, NOAA Fisheries required that the Council report to NOAA Fisheries annually regarding the impact of ocean fisheries to winter-run chinook thus providing the opportunity for accumulating additional information and making adjustments as necessary. This established the expectation that fisheries would be managed adaptively in response to new information.

<u>1996 and 1997 Biological Opinion</u>

Prior to the start of the 1996 season NOAA Fisheries concluded that there was sufficient information to warrant a reconsideration of its 1991 biological opinion. The resulting 1996 opinion was supplemented in 1997 to consider another increment of related data. Because the logic and outcomes of the two opinions were closely related they are described here as a pair with particular attention to the 1997 opinion (NMFS 1996, 1997).

The new information that prompted the reinitiated consultation was both negative and positive in nature. The escapement in 1994 (153) was a near record low. By this time there was real concern about losing one or more of the three consecutive cohorts. The 1994 brood year would be affected primarily by the 1996 ocean fishery highlighting the need for more stringent action.

By this time there was also new information related to ocean harvest impacts. The CWT data from the Coleman Hatchery releases indicated that the impact rates on winter-run chinook (catch/(catch + escapement)) in the 1994 and 1995 fisheries were 0.54 and 0.19. These estimates became available prior to the 1996 and 1997 planning seasons. As indicated earlier, these estimates were based on very limited data. However, they still represented "best available information" and could not be ignored. Results from the 1994 fishery in particular suggested that harvest impacts were not much different from those in the early 1970's developed from the fin clip data.

On the positive side, there was further evidence that significant actions had been taken to address harmful habitat conditions and that those actions were beginning to provide the expected benefits. Modifications at RBDD had been phased in, temperature problems reduced by providing cold water releases at Shasta Dam, and irrigation diversions had been screened. These and other significant actions were described in a table in the 1996 opinion which is reproduced here (Table 1). These were permanent changes in operation that would have ongoing benefits to survival.

Table 1. Actions taken to improve freshwater habitat for winter-run chinook salmon; the year that these actions were implemented and should have improved survival during spawning and rearing; and the year that those actions are expected to contribute to increasing escapement.

Freshwater Habitat Improvements	Actions and/or Benefits	Implement. Year	Year of expected benefit to escapement
Water temperature in the upper Sacramento River improved	•92-96% survival of eggs	•1989	•1992
	•70-80% survival of eggs	•1990	•1993
	•90-95% survival of eggs	•1991	•1994
	•90% survival of eggs	•1992	•1995
	•>99% survival of eggs	•1993	•1996+
Iron Mountain Mine water quality problems reduced	•Emergency treatment plant --reduced spills' toxicity	•1988-1994	•1991-1997
	•Upper Spring Creek diversion--reduced spills' toxicity & duration	•Jan 1991	•1993
	•Full-scale treatment plant --reduced spills' toxicity & duration	•Oct 1994	•1998
Red Bluff Diversion Dam - fish passage improved	•Dec-Apr gates up	•1989	•1992
	•Dec-May gates up	•1990	•1993
	•Nov-May gates up	•1991-1992	•1994-1995
	•Sep-May gates up	•1993-pres.	•1996+
Ramping flows from Keswick Dam	•Reduced stranding and dewatering	•1993-pres.	•1996+
ACID diversion	•Screening	•1993	•1996+
GCID operations	•Improved hydraulic conditions for fish passage	•1992	•1995+
Delta pumping operations improved	•DCC gates closed	•1992	•1995
	•DCC gates closed & QWEST improved	•1993-1994	•1996-1997
	•DCC gates closed & export/inflow ratios	•1995-pres.	•1998+

Finally, by 1996 and particularly 1997 there was increasing evidence of an initial, positive population response and recovery. The opinion provided estimates of an adult 3-year replacement rate. The geometric mean of the replacement rate averaged 1.35 for the five years beginning in 1989 indicating a mean population growth rate of 35% per generation (Table 2). Even the 1994 brood was slightly higher than the primary contributing brood in 1991. Because of the breadth and scale of habitat actions, there was reason for cautious optimism that many of the causes for the decline of the species had been addressed and conditions had improved sufficiently to allow for population growth.

Table 2. RBDD counts of adult winter-run chinook spawning escapement and adult 3 year replacement rates for 1989 - 1996 (from the 1997 biological opinion).[1]

Year	Adult Spawners	Adult 3 Year Replacement Rate
1989	480	2.34
1990	425	0.63
1991	134	1.14
1992	1122	1.16
1993	267	2.29
1994	153	
1995	1296	
1996	612	
	geometric mean	1.35

[1]RBDD estimates available at the time of the opinion. The RBDD time series was recalculated in 2001. Currently available estimates therefore do not compare directly to those reported in the 1997 opinion.

Despite the apparent improvements in habitat conditions and the status of the species, NOAA Fisheries concluded that concerns for the 1994 brood year required a more substantive response, and that further harvest reductions were necessary and appropriate. In the 1996 opinion NOAA Fisheries sought to provide a more quantitative standard for ocean fishery management. The basis of the calculations was updated and improved in 1997. In the 1997 opinion, NOAA Fisheries required that the ocean fishery be managed so that there was an 80% probability that the 3-year adult replacement rate was at least 1.0 (i.e., the population would remain stable or exhibit positive growth). Given the variability in the adult replacement rate observed between 1989 and 1993, the criterion was met if the adult replacement rate was increased by 31%. A 31% increase in the base period rate of 1.35 required an increase in the expected replacement rate to 1.77[2].

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[2]The probabilities associated with the adult replacement rates were determined as follows. It is assumed that the adult replacement rate R is distributed as a lognormal random variable, with mean μ and variance σ^2 on the log-scale: $R \sim \text{lognormal}(\mu,\sigma^2)$. For any given $\mu = \mu^*$, it follows that the probability of positive growth for any particular generation is

$$\Pr\{R \geq 1\} = \Pr\{\log(R) \geq 0\} = \Pr\{t_{df} \geq -\mu^*/\hat{\sigma}\},$$

where t_{df} is a t-distributed random variable with df = n-1 degrees of freedom, $\hat{\sigma}^2 = s^2(1+1/n)$, $s^2 = \Sigma(y_i-\bar{y})^2/(n-1)$, and $\bar{y} = \Sigma\, y_i/n$ for the observed $y_i=\log(R_i)$ data.

For the 1989-1993 brood years: n = 5, $\bar{y}$ = .298, s^2 = .304778, and $\hat{\sigma}^2$ = .3657336. Thus, for example, with

NOAA Fisheries recognized that the probability of achieving positive future growth rates was based on limited data and several assumptions, and that the population may grow faster or slower depending on future in-river and ocean survival conditions. However, these estimates provided a means to evaluate the relative benefits to the population of decreasing harvest impacts from current levels. With respect to the ocean fisheries, a complete closure of the chinook fisheries within the geographic range of winter-run chinook would have been the strongest possible measure that could have been used to increase escapement and promote recovery. However, NOAA Fisheries made an explicit policy decision to use the 80% probability for achieving positive population growth as the management criterion. The 1997 opinion had a term of 5 years with the intent of applying the standard through 2001 unless there was evidence suggesting the need for further review.

From a practical perspective, NOAA Fisheries' jeopardy standard required a 31% decrease in harvest impacts related to the 1989-1993 base period. This was accomplished through the use of additional time and area closures and changes in size limits particularly with respect to early season recreational fisheries. As an example Figure 6 shows projected landings under base period conditions and those projected for the 2001 season based on estimates from the WCOHM.

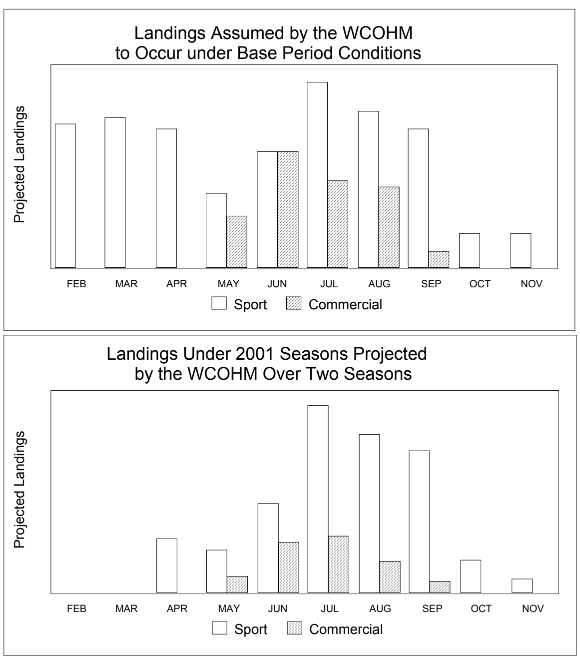

Figure 6. Top panel: distribution of landings of winter-run chinook used by the WCOHM to represent the base period 1989-1993. Bottom panel: distribution of landings projected by the WCOHM to occur under the 2001 season.

$\mu^* = .569$, $\Pr\{t_4 \geq -.569/\sqrt{.3657336}\} = .80$. On the unlogged scale exp(.569) = 1.77; a 31% increase over the 1989-1993 geometric mean of exp(.298) = 1.35.

2002 Biological Opinion

NOAA Fisheries again considered the status of winter-run chinook and related ocean fisheries impacts prior to the 2002 season following the five year term of the 1997 opinion (NMFS 2002). There was again new information that was pertinent to the review.

The 1997 opinion relied to a large degree on early indications of positive population growth. Information available at the time indicated that the 3-year adult replacement rate had increased by an average of 35% over the five preceding years. During the six years that the requirements of the 1996 biological opinion and 1997 amendment were in effect, additional estimates of adult spawner abundance based on carcass survey data also became available: six years using the Petersen method, and 2 years using the Jolly-Seber. When compared to the population estimates based on the RBDD counts, the magnitude of the abundance estimates differ, but the trends are similar (Figure 7). The six years of Petersen estimates provide three adult replacement rates: 2.7, 3.4 and 1.9. The replacement rate targeted by the 1997 opinion was 1.77. The escapement estimates for 2000 and 2001 were 6,600 and 11,500 (Petersen); 4,300 and 7,200 (Jolly-Seber); and 1,400 and 5,500 (RBDD passage). NOAA Fisheries' draft Sacramento River winter-run chinook recovery plan (NMFS 1997) suggested 10,000 females as a possible delisting goal.

Although the 2002 escapement estimates were not available prior to completion of the 2002 opinion, escapements have continued to rise. The escapement estimates from the Petersen, Seber-Jolly, and RMDD counts were 10,500, 7,300, and 9,200, respectively. The adult replacement rate calculated for the 1999 brood year from the recent Petersen estimate was 4.9.

Since the 1997 opinion the Livingston Stone Hatchery had opened. This was a conservation hatchery built specifically to contribute to the recovery of winter-run chinook. The hatchery helps mitigate risk of catastrophic failures, accelerate rebuilding, and provide opportunity to mark fish and develop critical information on survival rates, ocean distribution and harvest impacts that were otherwise not available.

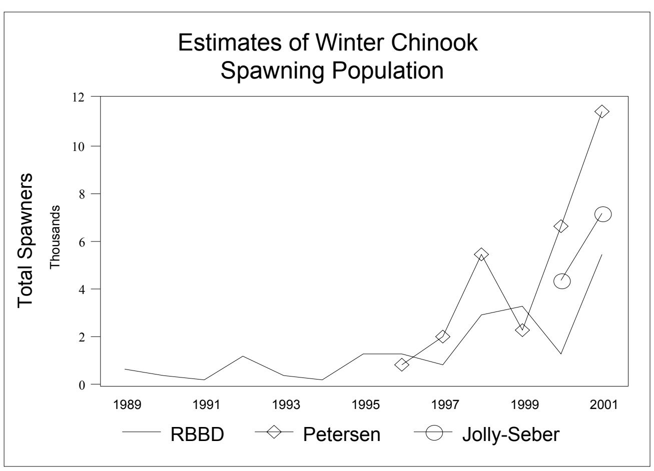

Figure 7. Three estimates of Sacramento River winter-run chinook spawning population abundance since the ESU was listed in 1989.

Given the circumstances, NOAA Fisheries concluded that further reductions in ocean fisheries were not needed. Instead, NOAA Fisheries fixed the season structure and thereby sought to limit the relative impact rate to that observed in recent years. The 2002 opinion was implemented for two years through 2003 to allow time to develop further information and management tools, and continue to assess the progress toward recovery.

NOAA Fisheries considered extending the requirements of the 1997 opinion that relied on a statistical methodology for specifying the magnitude of the required increase in adult replacement rates. Attempts to apply that methodology to the recently revised base period escapement estimates (and lower mean replacement rate) raised significant concerns regarding the sensitivity of the method to the small number of replacement rates in the base period (only 5) and the sensitivity of the base period replacement rates to small changes in the number of spawners. NOAA Fisheries also shared the concerns raised by the PFMC's Salmon Technical Team regarding use of the Winter Chinook Ocean Harvest Model to implement the requirements of the 1997 opinion (NMFS 2002). Instead of extending the specific requirements of the opinion NOAA Fisheries initiated a process designed to develop management objectives to provide necessary protection for winter-run chinook and improve on the methodology available at the time to assess the effects of fishing on winter-run chinook replacement rates. The two year time frame provided an opportunity to use anticipated information on ocean harvest distribution and impacts from CWTed fish released from the Livingston Stone Hatchery.

Future Review – Monitoring

Information related to abundance, and ocean distribution and fishery impacts will be key to future harvest-related consultations. Spawning ground carcass surveys will continue. Efforts are underway to refine the associated Seber-Jolly and Petersen mark-recapture estimates. These will be used to supplement ongoing counts at RBDD and provide alternative estimates of abundance.

Completion of the Livingston Stone Hatchery provides the opportunity for continued future releases of CWTed winter-run chinook. These will be instrumental for building a time series of ocean exploitation rate estimates, and a better understanding about ocean distribution.

Ocean fisheries have been reviewed through a series of consultations since 1991 in order to respond to developing information. The 2002 opinion was written to cover two years through 2003 to provide time to confirm the upward trend in abundance and review developing information from the CWT program. The available time is also being used to develop alternative jeopardy standards. The next consultation is scheduled to precede the 2004 fishery.

Summary

Winter-run chinook were not expected to survive construction of Shasta Dam which blocked off all of their spawning habitat without passage. The fact that winter-run did survive was a fortuitous result of the cold water provided to the area immediately below the Dam. By the mid-60s winter-run had apparently reestablished themselves, and were doing reasonably well with tens of thousands of returning spawners. However, subsequent habitat degradations, especially Red Bluff Diversion Dam, proved to be too much and the population began its precipitous decline to just a few hundred fish by the early 1990's. Although harvest impacts in ocean fisheries were not quantified, life history information suggested that impacts were relatively low. Harvest was therefore not identified as a primary factor of decline.

Given the circumstances there was policy direction to emphasize remedial actions that focused on the primary factors of decline. Ocean fishery closures were considered, but not implemented. Instead, the fisheries were initially capped in 1991 and further reduced as a result of the 1996 and 1997 consultations based on the expectation that the habitat-related remedies would be sufficient to achieve recovery objectives. By 2001 it was apparent that abundance and productivity was much improved. Fishery impacts have nonetheless been held at previously reduced levels. Future consultations will be based on developing information and the needs of the fish.

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CASE STUDY 2
UPPER WILLAMETTE RIVER CHINOOK

Overview

NOAA Fisheries considered a fishery plan for Upper Willamette River chinook from the Oregon Department of Fish and Wildlife (ODFW) for ESA compliance. Our review of the status of UWR chinook, and the environmental baseline and cumulative effects provided a context for analyzing the effects of the proposed fishery plan. There are two key findings of the resulting review. First, much of the historic habitat was blocked by hydro development or degraded by hydro operations or other habitat degradations. As a result, four of seven populations are now extinct or diminished to the point where they no longer support natural production. The capacity and productivity of the three remaining populations was also diminished to varying degrees. For now, it is necessary to consider the affect of the fishery plan on the existing populations recognizing that we will have to continually reassess the determination as recovery plans are developed and implemented.

Secondly, the Willamette River is dominated by hatchery production. Hatcheries were built to mitigate for lost production resulting from hydro development. Until recently fisheries were directed at hatchery fish with only secondary consideration for the needs of the wild fish. Hatcheries were identified as a significant factor of decline for the ESU at the time of listing. However, in response to the ESA listings and regional hatchery reform initiatives the hatchery program and the associated fishery plan have change. All hatchery fish are now mass marked with an externally visible adipose fin clip. The marking and revised release strategies allow key wild production areas to be managed for natural production without hatchery influence. The marking also allows for implementation of selective fisheries and a fishery plan that specifically limits the level of impact to wild fish.

Actions have been taken to improve the habitat in accessible areas. For example, water temperature control facilities have been completed and new bypass fish screens have been installed in the McKenzie River, improved flow management programs from the dams in the spring have been improved to benefit migrating adult and juvenile spring chinook, and numerous bank protection and stabilization projects have been completed throughout the Willamette Basin. However, our ability to assess the net affect on future survival of these improvements or further degradations that may occur is limited and qualitative at best. As a result, NOAA Fisheries' ESA determination regarding the fishery plan relies primarily on its review of changes in harvest and hatchery practices, the resulting reductions in harvest impacts, and a quantitative risk analysis that describes expectations regarding the population response. Conclusions of the risk analysis are supported by recent empirical evidence that shows increasing trends in key indicators of abundance and productivity.

Proposed Action/Fishery Plan

In 2000 the ODFW proposed a fishery plan that would apply to all freshwater fisheries in the lower Columbia and Willamette rivers affecting Upper Willamette River chinook. The proposed plan was a substantial deviation from past practice that previously allowed for nonselective fisheries directed at hatchery stocks or other stocks from outside the Willamette Basin. The new plan targets hatchery-origin chinook from the Willamette and elsewhere that are 100% mass marked with an adipose fin clip. Under the plan, all recreational and commercial fisheries are "selective" requiring the release of unmarked chinook. The incidental mortality of unmarked fish associated with catch and release is estimated. The fishery plan caps total mortality to natural-origin Upper Willamette River spring chinook at 15%. The expected average annual mortality rate associated with the fully implemented selective fishery is actually less, about 10% depending on which of the three indicator populations is considered. NMFS completed its review of ODFW's proposed fishery plan in February 2001 (NMFS 2001).

Upper Willamette River Chinook ESU

The Upper Willamette River chinook ESU includes native spring chinook populations in the Willamette River and its tributaries upstream of Willamette Falls, including naturally produced spring-run fish in the Clackamas River (Figure 1).

Upper Willamette River chinook salmon are one of the most distinct groups in the Columbia basin - genetically, in terms of age structure, and in terms of their marine distribution. The narrow time window available for passage above Willamette Falls (at Willamette RM 25) may have limited migratory access to the upper basin to spring periods of high flow, providing reproductive isolation and, thereby, defining the boundary of a distinct biogeographic region.

The Willamette/Lower Columbia River Technical Review Team (TRT) recently provided tentative conclusions regarding the historic population structure of the Upper Willamette River chinook. The TRT identified seven independent populations including the Clackamas, Molalla, North Santiam, South Santiam, Calapooia, McKenzie, and Middle Fork Willamette (Myers et al. 2002)(Figure 1).

Harvest Distribution and Trends

Upper Willamette River chinook are harvested in both ocean and inriver fisheries. Willamette chinook are a far-north migrating stock and, in the ocean, are caught primarily in fisheries of southeast Alaska and Canada. Because of their early return timing to freshwater (generally February - March) mature fish are subject to little impact in fisheries off

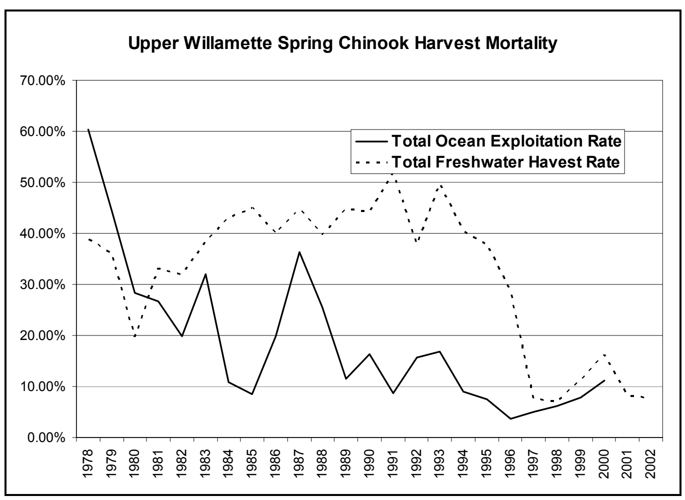

Figure 2. Ocean and harvest impacts on Upper Willamette River Spring chinook from 1978-2002.

the Washington coast that do not open until May 1. The total ocean exploitation rate has been quite variable, but averaged 26% from 1978 - 1990 (Figure 2). Since 1991 the ocean exploitation rate has averaged 9% as a result of ocean fishery reductions that were phased in progressively beginning in the early 1990s. The range of lower ocean exploitation rates seen in recent years should continue as a result of provisions for chinook management agreed to under the Pacific Salmon Treaty (for 1999 - 2008) that limit ocean fisheries relative to earlier decades. In the risk analysis discussed later, it was assumed that future ocean exploitation rates would average 12% with a 35% coefficient of variation.

Management changes and resulting harvest reductions in inriver fisheries occurred somewhat later. Through 1996 the inriver harvest rate averaged 39% (Figure 2). Since 1997 the inriver harvest rate has averaged 9%. Selective non-retention fisheries were first phased in in 2001 and fully implemented in 2002. The associated total harvest mortality to natural-origin Willamette chinook in the freshwater fisheries in 2001 and 2002 were estimated at 8.3% and 7.7%, respectively and were thus substantially lower than the harvest rate of 15% that was proposed as a management cap in ODFW's fishery plan.

Hatchery Program Review

Through the 1900's a network of dams was built that affected all of the major tributaries in the Willamette Basin. Several hatcheries were built explicitly to mitigate for the lost production resulting from these dams. There are currently five hatcheries operating in the Willamette Basin, four hatcheries located upstream from Willamette Falls (Marion Forks, South Santiam, McKenzie, and Willamette) and another on the Clackamas. The hatcheries release about 5 million spring chinook smolts per year. As a result, 85-95% of the spring chinook returning to the Willamette Basin are hatchery-origin fish.

In the past hatchery fish were released either directly from the facilities or, for purposes of "supplementation" in natural production areas such as the upper McKenzie and Clackamas basins. Hatchery stocks were often transferred among hatcheries to meet production goals. Only a subsample of releases were marked to provide information on survival rates, hatchery practices, and fishery contribution.

Concurrent with heightened concerns for wild fish populations, hatchery practices have been revised to minimize wild fish impacts. Fish are no longer transferred between hatcheries in order to promote the development of locally adapted broodstocks. Also hatchery releases are now localized to sites where straying into natural production areas is minimized and fishery opportunities are optimized. Outplanting of hatchery spring chinook into the upper Clackamas ended 1987, and in the upper McKenzie in 1990.

Further reforms were implemented in conjunction with the mass marking program. All hatchery-reared fish are now externally marked with an adipose fin clip so that hatchery and natural-origin fish can be distinguished visually. The mass marking program allows for: 1) selective fisheries that require the release of all unmarked fish, 2) development of locally adapted broodstocks, 3) selective removal of stray hatchery-origin fish from areas set aside for natural production, and 4) better assessment of the contribution of hatchery and natural-origin fish in areas where spawners continue to mix. The expanded hatchery fish marking program was phased in beginning with the 1996 and 1997 brood years, depending on location. As a result, by 2002 virtually all of the returning hatchery fish will be marked.

NOAA Fisheries conducted a separate review of the Willamette spring chinook hatchery programs for compliance with ESA. In the associated biological opinion, based largely on the above described reforms, NOAA Fisheries concluded that the hatchery programs will not jeopardize the continued existence of the listed Upper Willamette River chinook.

Population Status and Trends

Viable Salmonid Population Criteria

The fishery plan is evaluated in part based on the status and trends of the affected populations and with respect to its effects on the performance of each population consistent with NMFS' guidance on Viable Salmonid Populations (McElhany et al. 2000). NOAA Fisheries defines population performance in terms of abundance, productivity, spatial structure, and diversity and provides guidelines for each. The guidelines also distinguish between critical and viable population thresholds. Critical thresholds are those below which populations are at relatively high risk of extinction. Viability thresholds are those above which populations have negligible risk of extinction.

The effect of the fishery plan on populations is compared primarily to the abundance and productivity criteria that are the performance features most directly affected by a fishery of this type. The interim thresholds for abundance and productivity used in the analysis of the fishery plan are summarized in Table 1 and discussed in more detail in Oregon's proposed plan (ODFW 2001).

Population performance related to spatial structure and diversity is considered indirectly. Spatial structure is concerned primarily with the geographic distribution of a population. The proposed fisheries will have no habitat-level effects. The 15% impact rate cap associated with the proposed fishery plan is low and will not reduce population sizes to levels where the spatial distributions of populations are affected. Diversity concerns relate to a variety of life history characteristics of populations and may be a concern if different components of a population (e.g., older or larger fish) are subject to differential mortality rates. In this case, fishing impacts are spread over the duration of the run with all natural-origin fish released. As a result, no subcomponent of the populations will be selectively harvested at a rate substantially different than any other portion of the run. In addition, because of the low impact associated with the fishery, the selection pressure associated with any differential mortality that may occur will be limited.

There are no direct estimates of the size of the chinook salmon runs in the Willamette prior to

1946 when counts began at Willamette Falls. Estimates based on egg collections at salmon hatcheries suggest that the run size in the 1920's was on the order of 275,000 (Myers et al. 2002). Since 1946 the run size has generally ranged from 30,000 to 80,000 although, as discussed below, the majority of these fish are from hatchery production. Returns exceeded 100,000 during a four-year period beginning in 1988 and again in 2002 (Figure 3).

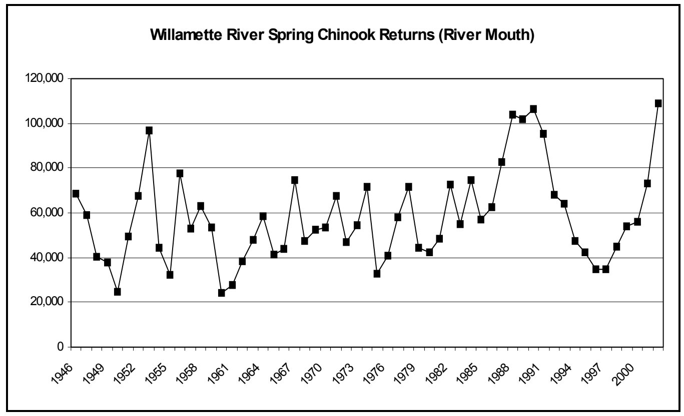

Figure 3. Returns of the Upper Willamette River Spring chinook to the mouth of the Willamette River.

Of the seven populations identified in the ESU those on the Molalla, South Santiam, Calapooia, and Middle Fork Willamette are likely extinct or diminished to the point where they no longer support natural production. Extensive hydro development blocked over half of the most productive spawning and rearing areas in the basin affecting all of the major tributaries occupied by spring chinook. Water management operations associated with these dams substantially changed seasonal water temperature profiles and thus also reduced habitat quality in downstream areas. (Relatively warm water released during autumn leads to the early emergence of stream-type chinook salmon fry, and cold water released during spring reduces juvenile growth rates.) Chinook populations in the basin were also affected by a dramatic decline in water quality in the lower Willamette River in the 1920s and 1930s (Myers et al. 2002). Populations continue to exist in portions of the Clackamas, North Santiam, and McKenzie rivers. The status of these populations is described in more detail below.

Clackamas River Basin

Although there is relatively little specific information, the Clackamas was presumably a major producer of spring chinook. However, from 1906-1939 access to spawning areas in the upper basin was severely impeded and finally blocked by River Mill and Faraday dams. During this period production in the Clackamas was limited to Eagle Creek and the lower 23 miles of the mainstem Clackamas. Passage to the upper basin was restored in the 1940s. By the 1950s it was apparent that the area had been recolonized. The origin of the recolonizing fish is uncertain, but likely resulted from a mix of Clackamas fish that persisted below the dams and strays from the upper Willamette tributaries (King et al. 2000). Genetic analysis suggests that naturally produced fish from the upper Clackamas are not distinct from hatchery stocks from the Upper Willamette River Basin (Myers et al. 2002).

Currently, most of the natural production in the Clackamas occurs in the mainstem and tributaries above North Fork Dam (RM 30). Much of the habitat in the upper basin is thought to be relatively productive and protected by its placement in National Forest areas and areas with Wild and Scenic River designation. There is also some limited spawning in the lower

Clackamas River below River Mill Dam.

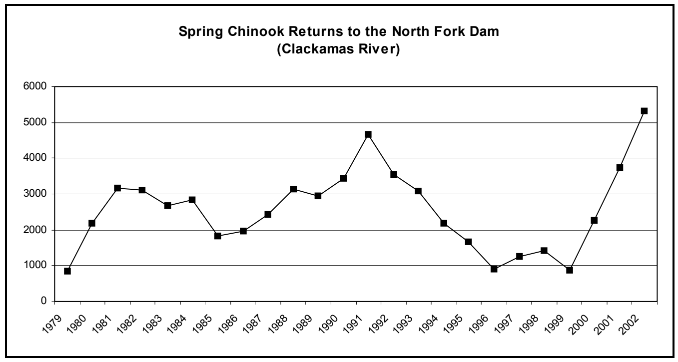

Figure 4. Returns of Upper Willamette Spring chinook to the North Fork Dam on the Clackamas.

From 1960 to 1979, after recolonization and before large-scale introductions of hatchery fish, escapement of naturally produced adults above the North Fork Dam averaged about 500 fish annually. Counts of spring chinook over North Fork Dam increased substantially in 1980 after the hatchery program was initiated (Figure 4; King 2003). Outplanting of hatchery-origin smolts to areas above the dam ended in 1987. The mass marking program was also initiated beginning with the 1997 brood year. By 2002 all returning hatchery fish were marked. Marked fish that stray up to the North Fork Dam are now removed. The upper Clackamas basin is therefore a key area that is managed specifically for the production of natural-origin fish.

Until the mass marking program was initiated, it was not possible to distinguish between hatchery and natural origin fish returning to the North Fork Dam. King (et al. 2000) estimated that the number of natural origin fish returning to the dam from 1994-1999 likely ranged between 500-1,500 compared to an average of about 500 fish annually that occurred prior to 1980. Returns in the last three years were 2,277, 3,748, and 5,329. Of the 5,329 fish returning in 2002, 2,281 were unmarked, natural-origin fish and only these were passed upstream.

An interim spawning escapement goal for the area above the North Fork Dam was developed based on a spawner-recruit analysis of adult escapement and the resulting juvenile production derived from smolt counts (ODFW 2001). Based on the analysis full seeding occurs at about 2,700 spawners. Fifty percent of full seeding (1,350) is used as an interim viable abundance threshold. An escapement of 1,350 would provide 83% of maximum juvenile production. An interim critical abundance threshold was set at 300. Escapements have been consistently well above the critical threshold and in recent years above the viable threshold as well.

Productivity thresholds are expressed in terms of increasing trends or positive replacement rates. Assessing productivity is complicated by the contribution of hatchery fish. From 1960 to 1979, absent hatchery influence, abundance was stable in the area above the dam. Abundance has been higher in recent years, suggesting on increasing trend. The advent of the marking program will allow for a more direct assessment of abundance and productivity thresholds in the future.

<u>North Santiam River</u>

More than 70% of the production capacity of the North Santiam system was blocked when Detroit Dam was built in 1953 without passage. Currently spawning and rearing habitat is available in the mainstem from Stayton, Oregon at RM 17 to Minto Dam at RM 44. However, as discussed previously, the production potential of this reach is likely diminished by temperature affects related to flow regulation. Some additional spawning and rearing habitat is available in the Little North Santiam, although redd surveys in recent years suggest use is relatively limited.

Survey methods for redd counts in the North Santiam were standardized beginning in 1996. Since then the number of redds observed in the mainstem have increased from about 130 to an average of 285 over the last 3 three years (Figure 5). The number of redds in the Little North Santiam has generally ranged from 10 to 40 but without apparent trend. There are no independent estimates for the number of spawners per redd for the system. In the McKenzie a multiplier of 4.5 fish/redd is used suggesting that the number of natural spawning fish in recent years exceeded 1200 per year. It is unclear how many of the spawners are stray hatchery fish. Available information suggests that natural production is quite limited. However, now that the hatchery-marking program is phased in, it will be possible to determine the origin of naturally spawning fish.

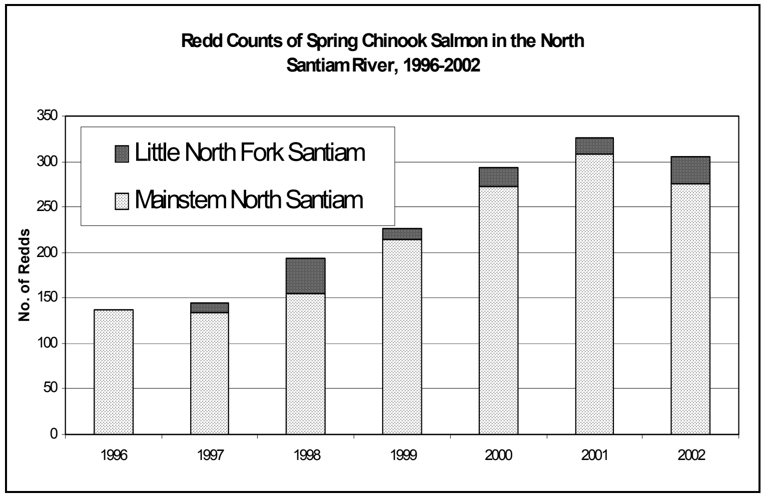

Figure 5. Redd counts of Upper Willamette River Spring chinook in the North Santiam River.

The North Santiam is also substantially influenced by hatchery production. Unlike other hatcheries in the Willamette Basin, the Marion Forks Hatchery largely avoided out-of-basin stock transfers (ODFW 1998a). The original genetic resource of the North Santiam is therefore best represented by the Marion Forks Hatchery stock. Genetic analysis of naturally produced juveniles from the North Santiam indicate that the naturally produced fish are most closely related to, although still significantly distinct from, other naturally and hatchery-produced spring chinook from the Upper Willamette and Clackamas rivers (Myers et al. 2002).

Recent spawning escapements in the North Santiam River likely do not meet critical and viable thresholds for abundance and productivity. Because of habitat limitations the capacity and productivity of the North Santiam is severally compromised. For the time being, the hatchery and natural production areas are being managed as an integrated system to maintain the genetic resources. The new marking program will provide estimates on how much natural production does occur, information that is not currently available. Further direction on the management of the North Santiam population may come through the recovery planning process. The harvest and hatchery programs will be reassessed at that time if necessary.

McKenzie River

Of the three remaining populations in the ESU, the McKenzie is the largest. Although several dams were built in the McKenzie River basin it still contains substantial high quality spawning and rearing habitat for natural production of spring chinook. Most of the remaining habitat is located above Leaburg Dam, although some spawning occurs below the dam as well.

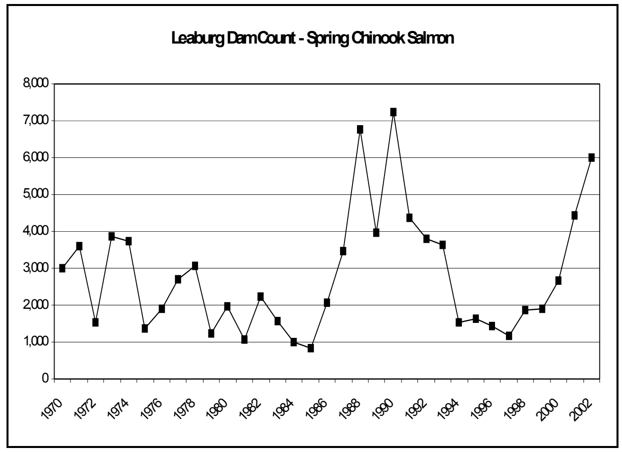

Figure 6. Returns of Upper Willamette River Spring chinook to the Leaburg Dam on the McKenzie River.

Since 1970 annual passage of adults over Leaburg Dam has ranged from 800 to 7,200 annually (Figure 6; King 2003). These were a mixture of hatchery and natural-origin fish. Beginning in 1994 the number of wild fish returning to the dam was estimated using coded-wire tag data. The number of wild fish returning to the dam increased steadily from 825 in 1994 to over 4,000 in 2002 (Figure 7).

The mass marking program was initiated with the 1996 brood year. By 2001 and particularly 2002 all or nearly all of the returning hatchery fish were marked. Hatchery fish returning to the dam are now sorted out so that only wild fish are passed above the dam. The McKenzie River above Leaburg Dam is managed specifically for natural-origin fish and is a key natural production area for the ESU like the upper Clackamas.

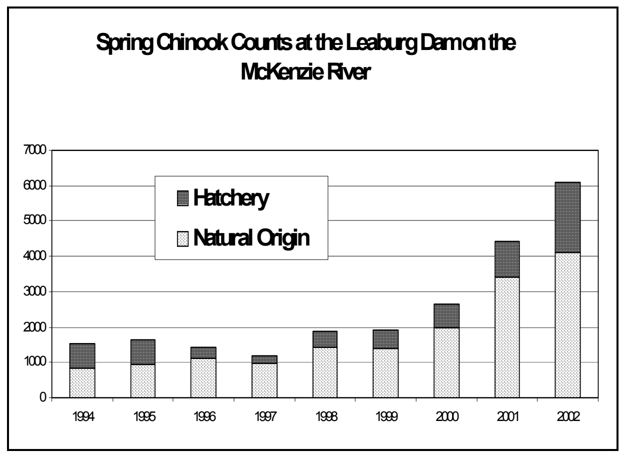

Figure 7. Returns of hatchery and natural-origin Spring chinook to the Leaburg Dam on the McKenzie River.

Estimates of redd counts and the associated number of spawners below Leaburg Dam are available since 1970 (King 2003). The number of fishing spawning below Leaburg Dam has averaged about 400 since 1994 with an increasing trend in recent years including over 950 in 2002. The origin of the fish spawning below the dam, whether hatchery or wild, and the associated productivity, is unknown. Leaburg Dam is a low head dam. As a result, unlike the Clackamas or North Santiam, the flow and temperature characteristics in the down stream area are relatively unaffected. Although lower elevation areas are generally not preferred habitat for spring chinook, it is likely that fish spawning below the dam do contribute to natural production. As with the other populations, the marking program will allow for better assessment of natural production in the future.

The interim critical abundance threshold of 600 was used by ODFW in their plan proposal (ODFW 2001) for the area above Leaburg Dam. There are no direct estimates of the production dynamics or capacity of the basin. However, production capacity was assumed to range from 3,000 - 5,000 based on habitiat considerations. Interim viability abundance thresholds were therefore set at 1,500 - 2,500 (50% of basin capacity). Returns of natural origin fish have therefore exceeded critical and viable abundance thresholds in recent years. Productivity thresholds are expressed in terms of increasing trends or positive replacement rates. The number of natural-origin fish returning to Leaburg Dam has increased steadily since 1994.

Risk Analysis

NOAA Fisheries ESA determination was based in part on a Population Viability Analysis that focused on the McKenzie River population. The model used in the analysis included a stock-recruitment relationship, normal variability in mortality rates, ocean and freshwater fisheries, and hatchery and wild components. Sensitivity analyses were used to explore the effects of parameter uncertainty. Key features of the analysis and the associated results are summarized here and described in more detail in Beamsderfer (2000).

The effects of fishing on the Upper Willamette River chinook populations were evaluated based on an analysis of extinction risk and recovery potential. Extinction risk was described as the probability of declining below a small population threshold where the ability to rebound was in question because of depensatory population processes or genetic effects. A "critical population threshold" of 300 spawners was used rather than an actual extinction level because recovery from single digit population sizes was assumed to be unrealistic. Use of the critical population threshold thus provided a "quasi-extinction risk" and was conservative relative to the actual risk of extinction. Sensitivity analyses were included to investigate the effect of the selection of the critical population threshold on risks associated with fishing.

Recovery potential was assessed by comparing the average number of spawners during the last 8 years of the 30 year simulations to a recovery benchmark that was set at 50% of replacement abundance. The analysis also considered the probability of achieving large run sizes as a component of the recovery standard because of the need to develop better estimates of productivity and capacity of the natural-origin populations. Recruitment estimates over a wide range of spawning escapements are needed so that future monitoring can more accurately estimate stock-recruitment parameters. "Large" run sizes were defined as >75% of the replacement abundance.

The population viability model consisted of a series of difference equations solved at annual intervals. Wild smolt numbers were estimated from wild spawners based on a Ricker function. (Sensitivity of model results to Beverton-Holt type recruitment was also explored.) All density-dependent mortality was thus assumed to occur during the freshwater rearing stage. To accurately reflect the reduced productivity potentially associated with depensatory processes at small population sizes, the model departed from the Ricker model at spawner numbers less than the critical population threshold. At spawner numbers between the critical population threshold and zero, the recruit per spawner rate was incrementally reduced to zero from the rate predicted by the Ricker curve at the critical population threshold.

The lack of an extended time series of age-specific return data precludes estimation of a stock-specific Ricker function for McKenzie River wild spring chinook. Therefore, risks were estimated for low, average, and high production cases based on observed stock productivities for other Columbia Basin stream-type chinook populations. Stock productivities were defined based on the Ricker function a-value which averaged 1.2 and ranged from 0.6 to 2.1 for 21 spring and summer chinook populations from 1974 to 1990 brood years. Ricker a-values of 0.7 and 2.0 used for modeling include approximately 90% of the observations for these 21 populations. The 1974 to 1990 brood year period encompasses a range of lower ocean productivity conditions typical of that period. Ricker a values averaged 2.51 and ranged from 1.29 to 3.44 for 13 populations prior to 1970 when favorable ocean conditions and fewer Columbia and Snake river mainstem dams provided for greater salmon survival. Productivities for the most recent return years have also been higher as indicate by recent very strong returns.

Carrying capacity of the McKenzie River for naturally-produced spring chinook was similarly unknown. The natural-origin population is generally assumed to be less than fully-seeded based on historic observations of larger run sizes although the effects of development and impoundment of several tributaries are unclear. Because of the uncertainty a plausible range of values was used for the replacement spawner abundance value of the Ricker function. Equilibrium values of 3,000 and 5,000 were used to represent cases where the habitat is currently assumed to be moderately and greatly under-seeded.

The model was used to assess the risk associated with a variety of harvest strategies. A range of fixed harvest rate and fixed escapement goal strategies were considered in addition to some mixed strategies based on those implemented in recent years. A zero freshwater harvest scenario was also analyzed for comparison.

Historic harvest rates associated with implementation of the Willamette management plan used prior to 1998 averaged nearly 40% in freshwater fisheries. The analysis indicated that there was a 31% risk that the McKenzie population would fall below the quasi-extinction threshold (300 spawners) if past practices were continued. There was also little chance of seeing large escapements near the replacement abundance or average escapements exceeding 50% of carrying capacity unless the stock was highly productive (Table 2). Alternatively, under a 15% fixed harvest rate strategy, the risk of falling below the quasi-extinction threshold was less than 0.1%. The probability of meeting the recovery criterion (50% of basin capacity) was also 0.50 under the most conservative assumptions. Under average or high productivity assumptions, the probability of meeting the recovery criterion was 0.95 or more. Under the 15% fixed harvest rate plan, the probability of meeting the large run size criterion during the last eight years of the simulation (75% of replacement abundance), ranged from 0.15 to 0.48 again depending on the assumed productivity. The proposed plan therefore provides for periodic large escapements needed to assess the production dynamics of the population. Table 2 and the discussion in Beamsderfer (2000) provide a more systematic review of the results of the model analysis.

ODFW's management plan for UWR chinook proposes to use a 15% harvest rate cap for all freshwater fisheries and as a safeguard against over harvest. However, the expected average annual harvest rate associated with implementation of selective harvest methods is about 10% depending of the population considered. If the actual harvest rates are consistent with expectations, the above described risk assessment provides conservative estimates of risk.

The risk assessment provides an expectation that the populations will be able to recover despite continuing impacts associated with the fishery plan. Fishery impacts have been reduced in recent years both in the ocean and inriver fisheries. Since 1997 the inriver harvest rate has averaged 9% and is thus consistent with expectations and limits prescribed by the fishery plan. Key abundance indicators at Leaburg Dam on the McKenzie and North Fork Dam on the Clackamas have been increasing in recent years and are currently at or above viability abundance criteria. Recent empirical data therefore supports the expectation of the risk assessment.

Future Review - Monitoring

The fishery plan identifies key parameters that will be monitored annually and used for assessing expectations regarding plan implementation and recovery. The fisheries will be monitored to assess impacts to hatchery and natural-origin fish. Population parameters will be monitored and compared to population specific abundance and productivity thresholds discussed above. (For details of the monitoring plan see ODFW 2001.) Results of the monitoring program will be provided to NOAA Fisheries annually by January 31 of each year (See for example King 2003.)

NOAA Fisheries' determination regarding the fishery plan is subject to reconsideration anytime that new information suggests that circumstances have changed and the no jeopardy determination should be reconsidered. In addition, periodic comprehensive reviews of the plan are scheduled for 2004 (after three years of plan implementation) and every five years thereafter. Formal recovery planning efforts are currently underway for Upper Willamette River chinook. The fishery plan will also be reassessed or revised if the assumptions or management strategies in the plan are inconsistent with analyses or recommendations developed through the recovery planning process.

Summary

Upper Willamette River chinook were substantially impacted by hydro development and related habitat degradations. Lost fish production resulting from the hydro development was mitigated through an extensive network of hatcheries located throughout the basin. The hatchery program was later identified as one of the significant factors of decline for the wild populations. Since the ESA listing the hatchery programs have been reformed to minimize impacts on wild populations. Among the reforms was the requirement that all hatchery fish be marked. The mass marking program in turn allowed for implementation of a mark-selective fishery in all freshwater fishing areas. As a result, harvest rates have been substantially reduced. A quantitative risk assessment was used to analyze the proposed fishing regime. The assessment indicated that there was little risk of extinction and a high probability of recovery. Key abundance indicators have been increasing in recent years and are currently at or above viability threshold levels. Recent empirical data therefore supports the expectation of the risk assessment. Necessary monitoring is in place with periodic reviews scheduled so that recovery expectations can continue to be assessed in the future.

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Figure 1. Upper Willamette River chinook area map.

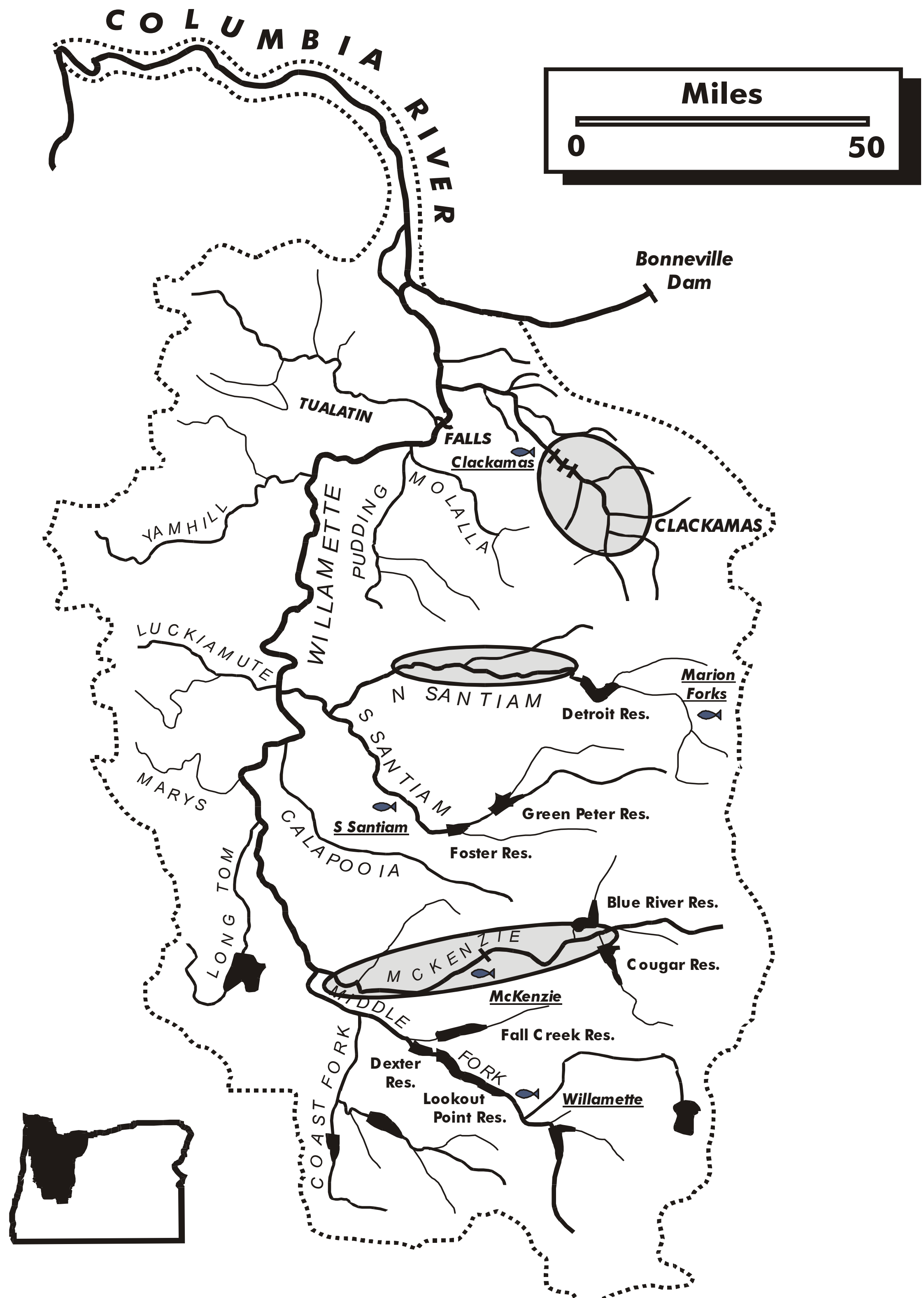

Table 1. List of the natural fish populations, "Viable Salmonid Population" thresholds, and associated hatchery stocks for natural populations of upper Willamette spring chinook. Note: these are interim designations and may change in the future as more information and analyses become available.

			Hatchery Stock	
Population	**Critical Thresholds**	**Viable Thresholds**	**Associated**	**Essential for recovery?**
McKenzie	*Abundance*: 600 spawning adults/year *Productivity*: Short term avg. replacement rate (3-year avg. spawners per spawner) projected to result in less than critical threshold number of spawners within 3 years (or) Abrupt declines in escapement (>50% in one year) relative to recent year average)	Interim *Abundance*: periodic escapements sufficiently large to estimate capacity & productivity *Productivity*: generally increasing trend Long term *Abundance*: average spawner numbers >50% of basin capacity defined under interim strategy *Productivity*: long term avg. replacement rate =1	McKenzie [1]	No
Clackamas	*Abundance*: 300 spawning adults/year *Productivity*: Short term avg. replacement rate (3-year avg. spawners per spawner) projected to result in less than critical threshold number of spawners within 3 years (or) Abrupt declines in escapement (>50% in one year) relative to recent year average)	Interim *Abundance*: periodic escapements sufficiently large to estimate capacity & productivity *Productivity*: generally increasing trend Long term *Abundance*: average spawner numbers >50% of basin capacity defined under interim strategy *Productivity*: long term avg. replacement rate =1	Clackamas [1]	No
North Santiam	*Abundance*: 300 spawning adults/year *Productivity*: Short term avg. replacement rate (3-year avg. spawners per spawner) projected to result in less than critical threshold number of spawners within 3 years (or) Abrupt declines in escapement (>50% in one year) relative to recent year average)	Interim *Abundance*: periodic escapements sufficiently large to estimate capacity & productivity *Productivity*: generally increasing trend Long term *Abundance*: average spawner numbers >50% of basin capacity defined under interim strategy *Productivity*: long term avg. replacement rate =1	N. Santiam [1]	No

[1]*Each wild population is associated with a subbasin hatchery stock. All other Willamette Basin hatchery stocks are commingled during a portion of the freshwater migration.*

Table 2. Effects of fishing on quasi-extinction risk based on the probability of fewer than 300 natural spawners, probability of returns exceeding 75% of the assumed replacement abundance (P_r), average spawner number in during the last 8 simulation years, and probability of last 8-year average run size exceeding 50% of basin capacity for low (a = 0.7), average (a = 1.2), and high (a = 2.0) productivity spring chinook stocks. Fishing options are sorted by increasing risk.

	P_r = 3,000			P_r = 5,000		
Fishing Option	*a = 0.7*	*a = 1.2*	*a = 2.0*	*a = 0.7*	*a = 1.2*	*a = 2.0*
Quasi-extinction risk						
No inriver fishing	<0.001	<0.001	0.004	<0.001	<0.001	<0.001
Harvest rate fixed at 5%	<0.001	<0.001	0.004	<0.001	<0.001	<0.001
Harvest rate fixed at 10%	<0.001	<0.001	0.003	<0.001	<0.001	<0.001
Harvest rate fixed at 15%	<0.001	<0.001	0.002	<0.001	<0.001	<0.001
Harvest rate fixed at 20%	<0.001	<0.001	0.001	<0.001	<0.001	<0.001
Falls esc. fixed at 50,000	0.008	0.001	<0.001	0.002	<0.001	<0.001
Revised Willamette Plan	0.039	0.001	<0.001	0.009	<0.001	<0.001
Harvest rate fixed at 40%	0.050	0.001	<0.001	0.013	<0.001	<0.001
Old Willamette Plan	0.314	0.013	0.002	0.197	0.004	0.002
Falls esc. fixed at 30,000	0.437	0.071	0.022	0.358	0.038	0.021
Large run size probability						
No inriver fishing	0.346	0.464	0.513	0.294	0.433	0.510
Harvest rate fixed at 5%	0.303	0.429	0.503	0.248	0.394	0.502
Harvest rate fixed at 10%	0.258	0.393	0.493	0.197	0.363	0.491
Harvest rate fixed at 15%	0.210	0.357	0.481	0.147	0.325	0.478
Harvest rate fixed at 20%	0.160	0.313	0.464	0.104	0.277	0.461
Harvest rate fixed at 40%	0.022	0.145	0.346	0.004	0.122	0.335
Falls esc. fixed at 50,000	0.008	0.111	0.387	0.001	0.073	0.347
Revised Willamette Plan	0.004	0.052	0.251	<0.001	0.032	0.224
Old Willamette Plan	0.001	0.120	0.155	<0.001	0.006	0.146
Falls esc. fixed at 30,000	<0.001	0.003	0.082	<0.001	0.001	0.064
Average spawner number in years 22 to 30						
No inriver fishing	2,290	2,440	2,490	3,800	4,250	4,180
Harvest rate fixed at 5%	2,070	2,390	2,480	3,470	3,990	4,090
Harvest rate fixed at 10%	1,920	2,290	2,350	3,060	3,810	3,950
Harvest rate fixed at 15%	1,700	2,190	2,360	2,760	3,660	3,890
Harvest rate fixed at 20%	1,490	2,010	2,290	2,400	3,320	3,770
Falls esc. fixed at 50,000	860	1,590	2,080	1,310	2,580	3,400
Harvest rate fixed at 40%	660	1,390	1,940	980	2,340	3,200
Revised Willamette Plan	540	1,280	1,890	780	2,080	3,070
Old Willamette Plan	200	820	1,570	300	1,320	2,600
Falls esc. fixed at 30,000	100	550	1,220	150	840	1,920

Probability of "recovery" within 30 years

No inriver fishing	0.85	0.98	1.00	0.84	0.99	1.00
Harvest rate fixed at 5%	0.73	0.98	1.00	0.72	0.99	1.00
Harvest rate fixed at 10%	0.65	0.98	1.00	0.63	0.97	1.00
Harvest rate fixed at 15%	0.52	0.96	1.00	0.50	0.95	1.00
Harvest rate fixed at 20%	0.41	0.92	1.00	0.38	0.92	1.00
Falls esc. fixed at 50,000	0.01	0.88	1.00	0.01	0.86	1.00
Harvest rate fixed at 40%	0.02	0.51	1.00	<0.01	0.48	1.00
Revised Willamette Plan	<0.01	0.50	1.00	<0.01	0.45	1.00
Old Willamette Plan	<0.01	0.04	0.99	<0.01	0.03	1.00
Falls esc. fixed at 30,000	<0.01	<0.01	0.88	<0.01	<0.01	0.85

CASE STUDY 3

PUGET SOUND CHINOOK

Overview

NOAA Fisheries considered the effect on Puget Sound chinook of salmon fisheries in Puget Sound and the Strait of Juan de Fuca managed by the State of Washington and Puget Sound Tribes during 2004. The Puget Sound fishery consultation provides an example of a complex management scenario involving an ESU with many populations of varying status that are subject to markedly different effects resulting from the proposed fishery.

To understand the basis of NOAA Fisheries' determination regarding the proposed fishery, it is necessary to describe the environmental baseline, and the status and effect of the proposed fishery on each population. Because of the complexity of the ESU which includes 22 populations, the status review is organized by stratifying the populations by region, life history, and watershed category. Where possible the effect of the fishery on populations was evaluated using a quantitative risk assessment. For other populations the evaluation was more qualitative and relied in particular on criteria described in NOAA Fisheries' Viable Salmonid Population paper which provided bench marks for assessing the status of populations. This included, for example, the use of critical and viable escapement thresholds, and past and present trends as indicators of abundance and productivity. Other more qualitative criteria were also included in the analysis such as the magnitude of past reductions in harvest, the relationship of the natural-origin population with its associated hatchery production and the practical effects of potential further reductions in harvest. The available information was used to characterize the effect and associated risk of the proposed action to each population. The ESA determination was then based on a consideration of the effect of the proposed fishery on the ESU as a whole.

The following review describes the proposed action, reviews the population structure of the ESU and the status of each population, and describes in some detail the more quantitative Viable Risk Assessment Procedure. The summary reviews the results of the quantitative and qualitative assessments, and how the available information was used in the final determination.

Proposed Action/Fishery Plan

Washington State and the 17 Puget Sound Tribes (co-managers) manage salmon fisheries in Puget Sound and the Strait of Juan de Fuca. These include recreational, commercial, and ceremonial and subsistence fisheries in marine and freshwater areas (see Figure 1). This Case Study describes NOAA Fisheries ESA review of the state and Tribes' proposed fisheries for the 2004 fishing year. This was the third in a sequence of ESA reviews that have occurred since Puget Sound chinook salmon were listed including one year proposed fishing regimes in 2000 and 2003, and a two year proposal for the 2001 and 2002 fisheries (NMFS 2000a; NMFS 2001a; NMFS 2003a; NMFS 2003b). These short-term reviews provided the opportunity to refine both the fishery plan and the assessment methods. NOAA Fisheries is currently reviewing a longer term fishing plan that would cover fisheries for the period from 2005 - 2009. Although there will be further refinements from the 2004 example, the fishery plan and assessment methods will be similar to those described here.

The purpose of the co-managers' plan is to limit impacts on weak, listed chinook populations, in order to ensure their survival and avoid impeding their recovery, while providing sufficient opportunity for the harvest of other species, abundant returns of hatchery-origin chinook, and available surpluses from stronger natural chinook stocks. The co-managers' fishery plan therefore seeks to strike a balance between their biological and policy objectives. The plan includes biologically-based management objectives that are generally expressed in terms of population-specific exploitation rates or escapement goals. In general, the fisheries are managed to achieve the biologically-based management objectives. Fisheries would be shaped and reduced as necessary to achieve the biological objectives, but there is a base level, referred to as a minimum fishing regime, below which the fisheries would not go. The minimum fishing regime is triggered by population-specific low abundance thresholds and defines the degree to which southern U.S. fisheries would be reduced when populations are at very low abundance or Canadian fisheries make it difficult or impossible to achieve the exploitation rate objectives, referred to as Rebuilding Exploitation Rates or RERs. From the co-managers perspective, the fishery plan addresses conservation concerns, provides at least limited harvest opportunity, including some recognition for the Tribes treaty rights, and represents a fair distribution of the burden of conservation.

The plan recognizes that survival and recovery will depend, over the long term, on necessary actions in other sectors, especially habitat actions. There is an ongoing recovery planning effort for the Puget Sound chinook salmon ESU. Completion of the recovery plan and decisions regarding the form and timing of recovery efforts described in the recovery plan will determine the kinds of harvest actions that may be necessary and appropriate in the future. Absent that guidance, NOAA Fisheries had to evaluate the proposed fishery plan for 2004 by examining the impacts of harvest within the current context. Therefore, we evaluate the future performance of the population under current productivity conditions, i.e., assuming that the impact of hatchery and habitat management actions remain as they are now.

NOAA Fisheries analyzed the proposed 2004 fishery plan to assess whether it was consistent with a no jeopardy determination.

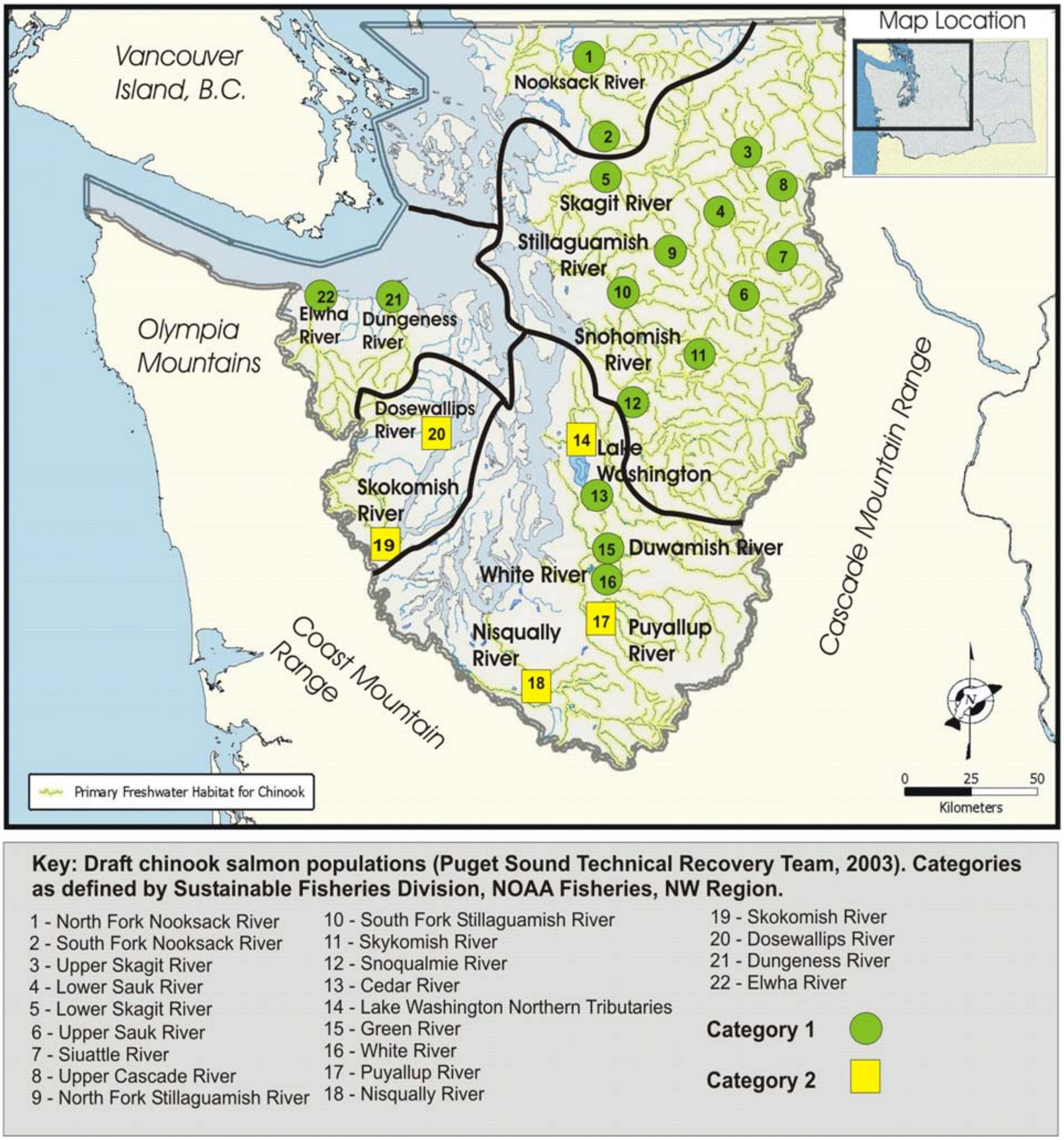

Figure 1. Location of Puget Sound chinook populations by watershed type and geographic region.

Puget Sound Chinook ESU

The Puget Sound Chinook ESU is one of the most complex ESUs of Pacific salmon. It includes all naturally spawned spring-, summer- and fall-runs of chinook salmon from south Puget Sound to the North Fork Nooksack and Elwha rivers in the north (Figure 1). NOAA Fisheries is currently delineating the population structure of this and other ESUs as an initial step in a formal recovery planning process that is now underway. By the time of the 2004 fishery review, the Puget Sound Technical Recovery Team (TRT) had tentatively identified 22 independent populations within the ESU (PSTRT 2003a; personal communication with M. Ruckleshaus, NMFS, January 18, 2004)(Figure 1, Table 1).

The status of Puget Sound chinook populations ranges from healthy to critical depending largely on the status of the habitat. Puget Sound includes areas where the habitat still supports self-sustaining natural production of chinook, areas where habitat for natural production has been irrevocably lost, and areas where chinook salmon were never self-sustaining. In some areas indigenous populations persist, whereas populations in other areas are a composite of indigenous stocks and introduced hatchery fish that may or may not be of local origin. In some areas where natural production has been lost, hatchery production has been used to mitigate for lost natural production. Detailed information on each of the populations can be found in *Independent Populations of Chinook in Puget Sound* (PSTRT 2003a) and the *Salmon and Steelhead Stock Inventory* (WDF *et al.* 1993).

Overall abundance of chinook salmon in this ESU has declined substantially from historical levels, and several populations are small enough that genetic and demographic risks are likely to be relatively high. In its 1998 status review, NOAA Fisheries noted that the average potential run size (hatchery + natural) at that time was approximately 240,000 with natural spawning escapement averaging 25,000 (Myers *et al.* 1998). Since 1998, natural spawning escapement has averaged approximately 40,583 with increases in the spring, summer, and fall components (Figure 2).

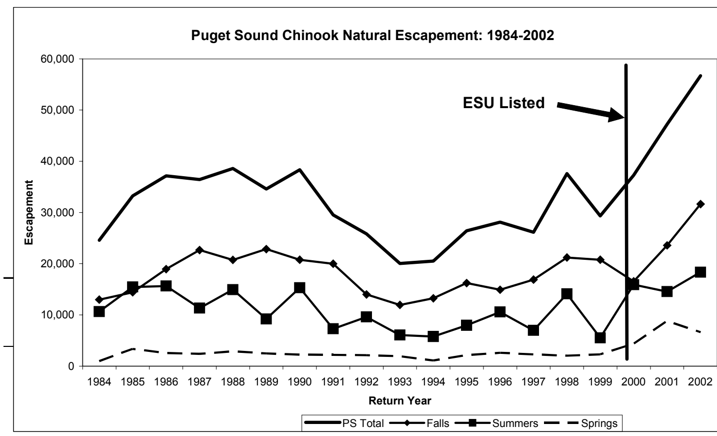

Figure 2. Escapement of naturally spawning Puget Sound chinook.

At the time of its original status review prior to listing, NOAA Fisheries listed habitat degradation, the extensive influence of hatcheries, and excessive harvest as factors of decline (Myers *et al*., 1998). All watersheds in Puget Sound have degraded habitat from a variety of causes such as logging, road building, agriculture, urbanization, flood control and hydropower. The degree to which each of these contributes to the decline in habitat quality or quantity varies from watershed to watershed. For example, the loss of large woody debris, critical for creating and maintaining chinook habitat, has exacerbated low flow conditions, resulting in increased sediment load and higher water temperatures, significantly reducing summer and winter rearing habitat. Increased sediment load resulting from a variety of land use practices has contributed to the loss of spawning, early incubation and winter rearing habitat in the Stillaguamish and Strait of Juan de Fuca systems (PSSSRG 1997). Dams constructed for flood control or power generation increase downstream and upstream passage mortality, change natural flow regimes, de-water or reduce flow to downstream areas, block the recruitment of spawning gravel, or result in elevated temperatures. For example, hydromodification in the Skagit system has resulted in a loss of 64% of its distributary sloughs and 45% of side channel sloughs.

The use of hatcheries in Puget Sound is extensive. Much of the hatchery production is for fishery augmentation, but hatcheries are increasingly important for conserving natural populations in areas where the habitat can no longer support natural production or where the numbers of returning adults are so low that intervention is required to reduce the immediate risk of extinction. However, there are also negative consequences associated with hatchery programs, particularly as they were developed and managed in the past. Significant contributions of hatchery-reared chinook to some systems, South Puget Sound in particular, mask trends in natural production. Domestication effects are concerns for hatchery programs in other areas. In response to the ESA listings and regional hatchery reform initiatives, hatchery programs and the associated fishery plans have changed. Broodstocks are managed to enhance and maintain the integrity of local populations by greatly reducing the prior practice of inter-basin transfers. For populations with a significant hatchery component, fisheries are now managed to provide primary protection to the naturally spawning chinook while shaping fisheries to maximize access to surplus hatchery production. The majority of Puget Sound chinook are now mass marked to assess the contribution of hatchery-origin adults on the spawning grounds, improve broodstock management, and allow for selective harvest opportunity where appropriate. Hatcheries in Puget Sound are currently the subject of an ESA review designed to evaluate both the beneficial and adverse effects of ongoing hatchery programs.

At the time of listing NOAA Fisheries expressed concern that exploitation rates of natural stocks in mixed-stock fishing activities might be excessive, as evidenced by declines in escapements of most stocks managed for natural escapement despite curtailed terminal fishing activities (Myers *et al.* 1998). Other data indicates that pre-fishing abundance for these stocks also declined presumably as a result of habitat degradation combined with poor ocean conditions. Increased escapements observed in recent years may be the result of improved ocean survival and evolving harvest management strategies implemented since the mid-1990s. Overall, exploitation rates on Puget Sound spring and summer/fall chinook have declined by 59% and 47%, respectively, since 1984, with most of the decrease occurring after 1992 (Figure 3)(FRAM 2003).

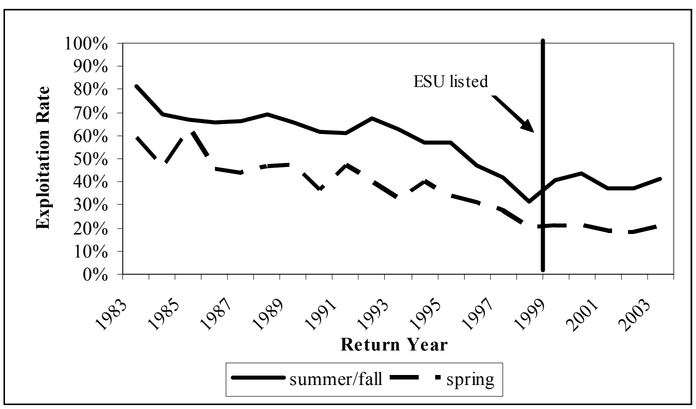

Figure 3. Exploitation rates on Puget Sound chinook.

One of the complications related to harvest is that some of the harvest occurs in Canadian fisheries outside the jurisdiction of the United States. For some Northern Puget Sound and Strait of Juan de Fuca populations in particular, as much as 80 percent of the harvest occurs in northern fisheries (CTC 1999). Although the fishery plan accounts for total fishing mortality wherever it occurs, and generally seeks to manage fisheries to meet biological objectives (e.g., exploitation rate or escapement goals), the state and Tribes' regulatory authority is limited to fisheries in the southern U.S. It is therefore necessary to consider the distinction between total harvest mortality and that which occurs within the jurisdiction of the state and Tribes when considering the effect of Puget Sound salmon fisheries on listed Puget Sound chinook salmon.

ESU Structure

Assessing the status of these populations requires review of the available data. The amount and quality of that data vary widely by population. Some populations have a long time series of reliable data; others only a few years. In some areas, the data is confounded by highly variable environmental conditions that make data collection difficult. In areas where hatchery fish contribute to spawning, techniques for distinguishing among hatchery and natural spawners have only recently been put in place as the importance of this information became more apparent. Information on the contribution of hatchery fish in natural production areas is therefore often relatively limited.

To help characterize the diversity of chinook populations in Puget Sound, NOAA Fisheries stratified the populations into five geographic regions and three life history types (spring, summer, fall) and relied on the Puget Sound chinook populations delineated by the Puget Sound TRT (PSTRT 2002; PSTRT 2003a). To help further describe the varied circumstances of populations in the ESU, Puget Sound populations have also been categorized based on the quality of the watershed habitat and the genetic integrity of the population (Figure 1, Table 1).

Category 1 populations are genetically unique and indigenous to watersheds of Puget Sound. Seventeen populations have been identified in this category (Figure 1, Table 1). Although hatchery and natural production is heavily integrated for some of these populations (Elwha, Dungeness, North Fork Nooksack, North Fork Stillaguamish, White, Green) genetic analysis indicates the indigenous genetic profile remains intact. In making its decisions on harvest actions, NOAA Fisheries' objective for Category 1 populations is to protect and recover these indigenous populations.

Category 2 populations are located in watersheds where indigenous populations may no longer exist, but where sustainable populations existed in the past and where the habitat could still support such populations. Five populations have been identified in this category (Figure 1, Table 1). These are primarily areas in Hood Canal and South Sound where hatchery production has been used to mitigate for natural production lost to habitat degradation. Consequently, these areas have been managed primarily for hatchery production for many years. Broodstock for the hatchery programs often came from areas outside these watersheds, most commonly the Green River. Natural spawning in these systems continues, but is primarily the result of hatchery-origin strays. Over time, the combination of low natural production and the heavy influence of the out of basin hatchery production is believed to have resulted in the loss of the indigenous stock. In making its decisions on harvest actions, NOAA Fisheries' objective for Category 2 populations is to use the most locally-adapted population to re-establish naturally-sustainable populations, and preserve options for alternatives that may be developed through recovery planning.

The Washington state and tribal fishery co-managers identified a third population category. Category 3 populations are generally found in small independent tributaries of Puget Sound that may now have some spawning, but never had independent, self-sustaining populations of chinook salmon. Many of these watersheds do not have the morphological characteristics needed for chinook and may be better suited for coho and chum salmon, cutthroat trout or resident freshwater species. Chinook salmon that are observed occasionally in these watersheds are primarily the result of hatchery strays since there is presumably little natural production. The TRT did not recognize chinook salmon spawning in Category 3 watersheds as populations because they were not determined to be independently spawning aggregations that would persist 100 years or more and thus, by TRT definition, are not populations (PSTRT 2003a). In making its decisions on harvest actions, NOAA Fisheries' objective for Category 3 is directed toward protection of other species and Category 1 and 2 chinook populations that transit these areas, but no specific harvest actions are proposed to promote the natural production of chinook salmon spawning in these watersheds.

Given the circumstances, NOAA Fisheries' consideration of Category 3 populations is not discussed further in this case study review.

Table 1. Puget Sound chinook populations stratified by geographic region, major life history type, and watershed category (NMFS 2001b, PSTRT 2002; PSTRT 2003a).

Geographic Region (PSTRT)	**Major Life History (WDF et al. 1992)**	**Watershed Category (NOAA Fisheries)**	**Population (PSTRT)**
(1) Strait of Georgia	spring	1 1	North Fork Nooksack South Fork Nooksack
(2) Whidbey/Main Basin	spring	1 1 1	Upper Cascade Upper Sauk Suiattle
	fall summer summer summer fall	1 1 1 1 1	Lower Skagit Upper Skagit Lower Sauk North Fork Stillaguamish South Fork Stillaguamish
	summer/fall	1 1	Skykomish Snoqualmie
(3) Southern Basin	fall	2 1 1 2 2	North Lake Washington Cedar Duwamish-Green Puyallup Nisqually
	spring	1	White
(4) Hood Canal	fall	2 2	Skokomish Mid-Hood Canal Rivers
(5) Strait of Juan de Fuca	fall	1	Elwha
	spring	1	Dungeness

Based on this framework, Category 1 populations are therefore the core populations that provide the focus for the analysis of proposed harvest actions. Consideration of harvest management impacts to Category 2 populations may be more important in regions that are not adequately represented by Category 1 populations. In the future, as a result of new information, Category 2 populations may be reclassified, requiring changes in their management objectives. For example, an outcome of recovery planning may be a recommendation that a particular Category 2 population be managed as a self-sustaining natural run and it would therefore be reclassified as a Category 1 population. It is important that current management not preclude future recovery options.

Because of the complexity of the ESU, NOAA Fisheries uses the geographic regions, life history types, and watershed categories described in Table 1 to assess whether proposed harvest actions adequately protect the diversity of populations within the ESU. Following is a brief description of the status of populations in each geographic region.

Population Status

In the following discussion abundance information is compared to critical and viable escapement thresholds to provide necessary context. (The threshold concept is discussed in more detail in the following sub-section on the Viable Risk Assessment Procedure.) Where adequate data exists, thresholds are based on population specific information. Where information is not available, thresholds are based on generic guidance from the scientific literature (McElhaney *et al.* 2000). Included in the status reviews is a summary of harvest rate trends and harvest distribution across fisheries that is used to determine how harvest has been addressed as a factor of decline and the effect of possible alternative harvest actions on fishing.

There are two spring chinook populations in the **Strait of Georgia Region**: the North Fork Nooksack and the South Fork Nooksack (Figure 1)(PSTRT 2003a). Both are watershed Category 1 populations and are managed for harvest objectives based on natural production. The two populations are genetically distinct from each other because of prevailing habitat conditions. One is strongly influenced by glacial flow; the other is not. Habitat conditions in both areas are substantially degraded due largely to timber harvest and associated road building activities. Straying between the two populations was historically low, as supported by available genetic data, but straying may have increased in recent years (PSTRT 2003a). The more recent straying observations may be partially due to an increase in hatchery production. This potential source of straying may have been reduced by the co-managers with the implementation of a 50 percent reduction in on-station hatchery releases from Kendall Creek Hatchery (personal communication with T. Scott, WDFW, March 22, 2004).

Natural origin escapement to the North Fork was below 300 (500 total) fish in all but two years from 1984 through 1998 compared to critical and viable escapement thresholds of 200 and 1,250. However, escapement has increased in recent years, averaging 180 natural origin spawners (3,438 total natural spawners[1]) since 1999 (Tables 2 and 3). However, the increase in recent years has been primarily due to large returns from a hatchery supplementation program at the Kendall Creek Hatchery. When compared to hatchery-origin returns, the lack of a similar dramatic increasing escapement trend in natural-origin fish, even in response to past harvest rate reductions, suggests constraints on productivity due to limitations in marine, estuarine or freshwater habitat. The annual spawning escapement to the South Fork ranged from 103 to 620 fish between 1984 and 2002, and the escapements have increased over pre-listing levels (Table 2). Escapement from 1999 through 2002 averaged 249 natural origin spawners (338 total natural spawners)(Table 2) compared to critical and viable escapement thresholds of 200 and 1,250.

[1]Natural origin spawners are those whose parents spawned in the wild. Natural escapement also includes adults produced from hatcheries and stray to the spawning grounds.

Table 2. Recent average annual escapement levels compared with NMFS-derived critical and viable thresholds for Puget Sound Chinook salmon management units and individual populations.

Management Unit	Population	1990 to 1998 Average Escapement	1999 to 2002 Average Escapement	Abundance Thresholds Critical[1]	Viable[2]	Trend since listing[3]	% change[4]
Nooksack	Natural-Origin Spawner:	297	429	*400*	*500*		
	North Fork Nooksack	144	180	*200*	-	Increasing	25%
	South Fork Nooksack	153	249	*200*	-	Increasing	63%
Skagit	Natural Spawners:	8,698	13,810	-	-		
Summer/Fall	Upper Skagit River	6,676	10,144	*967*	*7,454*	Increasing	52%
	Lower Sauk River	539	721	*200*	*681*	Increasing	34%
	Lower Skagit River	1,484	2,944	*251*	*2,182*	Increasing	98%
Skagit	Natural Spawners:	1,014	1,075				
Spring	Upper Sauk River	392	364	*130*	*330*	Stable	-7%
	Suiattle River	398	380	*170*	*400*	Stable	-5%
	Upper Cascade River	224	330	*170*	-	Increasing	47%
Stillaguamis	Natural-Origin	828	980				
h	Spawners:	557	697	*300*	*552*	Increasing	25%
	N.F. Stillaguamish River	271	283	*200*	*300*	Stable	5%
	S.F. Stillaguamish River						
Snohomish	Natural-Origin	2,627	3,936				
	Spawners:	1,625	2,118	*1,65*	*3,500*	Increasing	30%
	Skykomish River	1,003	1,818	*0*	-	Increasing	81%
	Snoqualmie River			*400*			
Lake	Natural Spawners:	624	767				
Washington	Cedar River	417	385	*200*	*1,250*	Stable	-8%
	Sammamish River	208	373	*200*	*1,250*	Increasing	79%
Duwamish-	Natural Spawners:						
Green River	Duwamish-Green River	6,737	9,299	*835*	*5,523*	Increasing	38%
White River	Natural Spawners:						
	White River	403	1,220	*200*	*1,000*	Increasing	203%
Puyallup	Natural Spawners:						
	Puyallup River	2,173	1,672	*200*	*1,200*		
	South Prairie Cr. Index	1,032	1,029			Stable	0%
Nisqually	Natural Spawners:						
	Nisqually River	893	1,318	*200*	*1,100*	Increasing	48%
Skokomish	Natural Spawners:						
	Skokomish River	981	1,503	*200*	*1,250*	Increasing	53%
Mid-Hood	Natural Spawners:						
Canal	Mid-Hood Canal Rivers	178	404	200	*1,250*	Increasing	127%
Dungeness	Natural Spawners:						
	Dungeness River	138	345	*200*	*925*	Increasing	150%
Elwha	Natural Spawners:						
	Elwha River	1,994	2,009	*200*	*2,900*	Stable	1%

[1] Critical threshold under current habitat and environmental conditions.
[2]Viable thresholds under current habitat and environmental conditions.
[3]Population trend was considered increasing if the 1999-2002 average escapement was 10% or greater than the 1990-1998 average escapement; decreasing if the 1999-2002 average escapement was 10% or less than the 1990-1998 average escapement; and stable if the 1999-2002 average escapement was within 10% of the 1990-1998 average escapement.
[4]The percent change in the post-listing 1999-2002 average escapement when compared to the pre-listing 1990-1998 average escapement.

Table 3. Natural-origin and natural spawners, North Fork Nooksack River, 1999 to 2002.

Management Unit	North Fork Nooksack River Population	1999	2000	2001	2002	1999 to 2002 Average
	Natural-Origin Spawners:	91	159	250	221	180
Nooksack	Natural Spawners [1]	911	1,365	4,057	7,419	3,438

[1] Natural spawners include first generation hatchery-origin adults that spawn in natural spawning areas.

Nooksack spring chinook tend to migrate northward. As a result, the majority of harvest mortality occurs in British Columbia, which accounted for approximately 68 percent of fishery mortality from brood years 1991 through 1998 (personal communication with D. Simmons, NMFS, April 1, 2004). On average, Alaskan fisheries accounted for 0 percent, Puget Sound commercial net and recreational fisheries for 30 percent, and Pacific coastal ocean fisheries for 2 percent (personal communication with D. Simmons, NMFS, April 1, 2004). The total exploitation rate on both populations has declined by 45 percent since the 1980's, averaging 74 percent from 1981 through 1984, and 41 percent from 1991 through 1998 brood years (personal communication with D. Simmons, NMFS, April 1, 2004).

Between 1992 and 2002, hatchery-origin adults accounted for, on average, an estimated 67 percent of naturally-spawning chinook salmon in the North Fork (PSTRT 2003b). There is no comparable supplementation program on the South Fork Nooksack. The Kendall Creek Hatchery stock retains the genetic characteristics of the wild population. Additionally, the co-managers are applying operational techniques that decrease the likelihood for divergence of the hatchery population from the extant natural population. Therefore, adult fish production resulting from the Kendall Creek Hatchery program help to buffer the genetic and demographic risks to the North Fork Nooksack River population.

The **Whidbey/Main Basin Region** includes the Skagit, Stillaguamish and Snohomish river systems (Figure 1, Table 1) . The three basins contain 10 chinook populations (PSTRT 2003a) which are all watershed Category 1 populations. These watersheds are hydrologically diverse, differ in the magnitude of hatchery production, and support populations with different life history strategies, including three of Puget Sound’s seven spring chinook runs and three of its five summer-run populations.

The Skagit River system contains six of the ten populations in the region including three spring, two summer; and a fall-timed population (PSTRT 2003a). Escapements generally declined steadily from the 1970s to the mid-1990s. However, the most recent 4-year period has shown increasing trends in escapement for four of the six populations and stable trends for the other two populations. The populations vary significantly in abundance and productivity. Escapement for the Lower Skagit fall, Lower Sauk summer and Upper Skagit summer populations averaged 2,944, 721, and 10,144, respectively, from 1999 through 2002 which exceeded their viable escapement thresholds of 2,182, 681 and 7,454, respectively. The three Skagit spring chinook populations are smaller, but comparable to each other in terms of abundance. Escapement for the Upper Cascade, Upper Sauk, and Suiattle spring populations averaged 330, 364, and 380, respectively, from 1999 through 2002 compared with viable thresholds of 330 and 400 for the Upper Sauk and Suiattle populations, respectively (Table 2). Data was unavailable to derive a viable threshold for the Upper Cascade population. Average productivity[2] for the 1990-97 brood years ranged from 1.6 to 3.9 recruits/spawner for the six Skagit chinook populations (PSTRT 2003b).

[2]The number of adult recruits produced per parent spawner.

As with the Nooksack spring populations, a significant proportion of the harvest related mortality occurs to the north, outside of the jurisdiction of the state and Tribes. Northern fisheries accounted for 46 and 52 percent of salmon fishing-related mortality for Skagit spring chinook and Skagit summer and fall chinook, respectively, from 1993 through 1998 brood years (personal communication with D. Simmons, NMFS, April 1, 2004; FRAM 2003). Exploitation rates for summer and fall chinook salmon populations fell 43 percent from levels in excess of 60 percent during 1985-88, to an average in recent years of 34 percent (FRAM 2003). Over the same period, exploitation rates for spring Chinook salmon fell 49 percent, from an average of 81 percent during 1981-84 brood years (primarily 1985-88 return years) to a recent average of 42 percent (personal communication with D. Simmons, NMFS, April 1, 2004).

The Skagit chinook populations are relatively unaffected by hatchery production. There is a small production facility on the Cascade River that serves primarily as an indicator stock for the coded-wire tag program to monitor survival rates, exploitation rates and harvest distribution. The contribution of hatchery-origin fish to natural spawning has been estimated at less than 2 percent (PSMFC 2002; PSTRT 2003b).

The Stillaguamish River includes two populations. Escapements to the North Fork Stillaqquamish declined from 1974 through 1991. Since then, there has been an increasing trend. The estimated average annual escapement from 1999 through 2002 was 697 natural-origin spawners (1,151 total) in the North Fork compared to critical and viable escapement thresholds of 300 and 552 (Table 2). There has been no significant trend in escapement in the South Fork Stillaguamish River which has averaged 283 since 1999 compared to critical and viable escapement thresholds of 200 and 300, respectively (Table 2).

A slightly higher proportion of the total harvest of the Stillaguamish Management Unit occurs in Canada than in Puget Sound. In recent years, approximately 16 percent of Stillaguamish fishing-related mortality occurred in Alaska, 51 percent in Canada, 33 percent in Puget Sound commercial and recreational fisheries, and less than 1 percent in Pacific coastal ocean fisheries (personal communication with D. Simmons, NMFS, April 1, 2004). Exploitation rates have fallen 43 percent since the mid-1980's from rates averaging 68 percent to approximately 39 percent in recent years (personal communication with D. Simmons, NMFS, April 1, 2004).

A conservation-based supplementation program was initiated on the North Fork Stillaguamish in 1986 using indigenous broodstock to help rebuild the population. Hatchery fish from the supplementation program were included in the ESA listing because they were considered essential for recovery. Hatchery-origin adults comprised 33 percent of the natural spawners in the North Fork from 1990 through 200 2 (PSTRT 2003b). There is no comparable program on the South Fork Stillaguamish. Straying of hatchery fish in the South Fork has not been quantified.

Two populations have been identified in the Snohomish River system: the Skykomish and Snoqualmie rivers. The Skykomish population includes both summer and fall-timed fish (PSTRT 2003a). Spawning escapement to the Skykomish River showed a marked declining trend from the late 1970s until 1993, and a substantial increasing trend since then. The average escapement from 1999 through 2002 was 2,118 natural-origin spawners (4,226 total) compared to abundance thresholds of 1,650 and 3,500 (Table 2). The trend in escapement for the Snoqualmie River population was relatively flat from the late 1970s to the mid-1990s. From 1999 through 2002, the average annual escapement of natural origin spawners was 1,600 natural-origin spawners (2,113 total) compared to a critical abundance threshold of 400. A viable escapement threshold had not been identified at the time of the 2004 review.

Approximately 25 percent of fishing-related mortality on the Skykomish and Snoqualmie populations occurred in Alaska and Canada, 6 percent in Washington ocean fisheries, and 69 percent in Puget Sound net and sport fisheries (CTC 2002). Exploitation rates have declined by an average of 62 percent from an average of 62 percent in the early 1980's to an average of 23 percent in recent years (FRAM 2003).

The primary objective of the hatchery program on the Snohomish system is fishery augmentation although it does rely on local-origin broodstock. From 1990 through 2002, an estimated 42 percent of naturally-spawning chinook in the Skykomish River and 23 percent of naturally-spawning chinook in the Snoqualmie River were of hatchery origin (PSTRT 2003b).

The **Southern Basin region** contains four major chinook-bearing watersheds including Lake Washington, and the Duwamish-Green, Puyallup and Nisqually rivers (Figure 1, Table 1). The Puget Sound TRT identified six populations in the region (PSTRT 2003a). Three of the populations are designated watershed Category 1 and three Category 2. Genetically, most of the present spawning aggregations in the South Puget Sound Region are similar, likely reflecting the extensive influence of transplanted stock hatchery releases, primarily from the Duwamish-Green River population (PSTRT 2003a). Most Chinook salmon in the South Puget Sound Region also have similar life history traits. Accordingly, the PSTRT found that life history and genetic variations were not useful in determining independent populations within the South Puget Sound Region. The lower reaches of all these system flow through lowland areas that have been developed for agricultural, residential, urban or industrial use. Natural production is limited by stream flows, physical barriers, poor water quality and limited spawning and rearing habitat related to timber harvest and residential, industrial and commercial development.

Long and short term trends in escapement for populations in the South Basin region have generally been positive (Table 2). However, the magnitude of hatchery fish on the spawning grounds is likely masking the true level of natural production (Myers et al. 1998; PSIT and WDFW 2004; WCBRT 2003). Except for the Cedar and Sammamish chinook populations, escapements in the other areas have exceeded their viable escapement thresholds in recent years (Table 2).The range of escapements in the former two populations include years in which escapements have come close to or have fallen below their critical escapement thresholds. However, in the case of the Cedar River population, recent comparisons of escapement estimation methods indicate more spawners may be present than previously thought. In the case of the Sammamish population, escapement estimates do not include escapement into some of the tributary areas. Therefore, a direct comparison of escapements with the VSP generic guidance of a critical threshold of 200 fish should be considered conservative, as the total escapements are likely greater.

Chinook in this region were managed for hatchery harvest rates for decades. Data collection has begun to try to assess system productivities and to quantify the contribution of hatchery strays to escapements, but it will be several years before sufficient data are available for analysis. Beginning in 2000, management transitioned in the Nisqually and Puyallup systems from a focus on hatchery management to management objectives based on naturally spawning adults. In South Puget Sound, past strategies to maximize harvest of hatchery stocks resulted in exploitation rates of 75 percent or more (Table 2). Unlike the populations in the Strait of Georgia and Whidbey/Main Basin regions, the majority of fishing-related mortality on Southern Basin populations has historically occurred in Puget Sound fisheries. For the 1991 through 1998 brood years (1993 through 2005 calendar years), Canadian fisheries accounted for approximately 4-39 percent of fishing-related mortality, Puget Sound commercial and recreational fisheries 50-95 percent, Pacific coastal ocean fisheries 1-9 percent, and Alaska fisheries 2 percent or less (CTC 2003). Total exploitation rates have declined by 14 to 63 percent, depending on the population, since the early 1980s averaging 68 to 90 percent in the 1980s, to 29 to 77 percent in recent years (Table 2).

Table 4. Recent year escapement for populations in the South Basin Region (PSIT and WDFW 2004; PSTRT 2003b)

Population	Escapement Thresholds		1999-2002 Average Escapement (range)	Average Exploitation Rates	
	Critical	Viable		1983-1988	1999-2003
North Lake Washington	200	1,250	373 (227-537)	78%[1]	29%
Cedar	200	1,250	385 (120 - 810)	78%[1]	29%
Green-Duwamish	835	5,500	9,299 (6,170 - 13,950)	79%[2]	44%
Puyallup	200	1,200	1,672 (1,193 - 1,988)	75%[1]	59%
White	200	1,200	1,220 (553 - 2,002)	77%[2]	39%
Nisqually	200	1,100	1,318 (1,079 - 1,542)	90%[2]	77%

Data Source: [1]FRAM 2003
[2]CTC 2003. Data are through 2000. Data for years 2001-2003 are not yet available.

Numerous hatcheries in this area account for the majority of chinook salmon produced in Puget Sound (PSMFC 2002). With the exception of the White River program, hatchery production in the region is primarily for fishery augmentation. Until recently inter-basin hatchery transfers were common and extensive with the Green River serving as the primary source for broodstock. Under a policy adopted by the co-managers in 1991, all Puget Sound hatchery programs established using Green River stock were required to become self-sustaining, and transports of Green River-origin broodstock between watersheds were prohibited. Because of the magnitude and duration of the earlier hatchery programs and the low natural production of these systems, there is no detectable genetic difference between the fish originating from the hatchery and those spawned in the wild (PSIT and WDFW 2004; WDF *et al.* 1993 as cited in PSTRT 2003a). Although stray rates have not been quantified for most areas, hatchery fish are believed to contribute heavily to the naturally spawning populations. For example, stray rates in the Green River averaged 72 percent from 1990 through 2002 (PSTRT 2003b).

Because the hatchery program on the Green River has not received out-of-basin stock transfers, the integrated Green River natural/hatchery-origin stock likely retains most of is genetic characteristics (Marshall *unpublished*) and is thus classified as a Category 1 population. The White River supports the only spring chinook population in the South Sound Region and is also believed to retain its original genetic characteristics, so it is also classified as Category 1. Because of chronically low abundance, a conservation-based hatchery program was initiated in the mid-1970s to help rebuild White River spring chinook salmon.

The **Hood Canal Region** has two fall chinook populations, one in the Skokomish River, and a second that is comprised of three Hood Canal tributaries (Dosewallips, Duckabush and Hamma Hamma Rivers)(PSTRT 2003a). Both the Skokomish and mid-Hood Canal Rivers populations are considered watershed Category 2 populations and thus are a composite of natural- and hatchery-origin fish that are genetically indistinguishable. Historically, the Skokomish River supported the largest natural chinook run in Hood Canal. Natural production in the North Fork Skokomish has been limited as a result of impacts associated with a hydroelectric dam that blocks anadromous passage at RM 21 and greatly limited in-stream flow due to an out of basin diversion. Natural production in the South Fork is further limited by the effects of intensive logging activity (WDF *et al.* 1993). Natural escapements to the Skokomish have increased from a pre-listing average (1990-1998) of 981 to a 1999-2002 average escapement of 1,503 total natural spawners. These averages compare to critical and viable escapement thresholds of 200 and 1,250, respectively (Table 2).

The Mid-Hood Canal Rivers population is the other independent Chinook salmon population within Hood Canal (PSTRT 2003a). A great deal of uncertainty remains about the relationship among the Chinook in the three rivers because of the lack of information about the populations prior to significant habitat alteration and use of hatchery supplementation in these rivers. Habitat differences do exist between these Mid-Hood Canal tributaries. The Dosewallips River is the only system in the snowmelt-transition hydroregion (PSTRT 2003a). Prior to 1986, all escapement estimates for these rivers were made by extrapolation based on observations from the Skokomish River (PSIT and WDFW 2004). Aggregate escapement to the three mid-Hood Canal rivers has averaged 404 since 1999 compared with generic critical and viable escapement thresholds of 200 and 1,250 (Table 2) although escapement has been highly variable, especially among the three tributaries. The 1999-2002 average escapements into these individual sub-populations range from 43 to 304 spawning adults.

The overall exploitation rate for Hood Canal summer-fall Chinook salmon declined by 49 percent since the early 1990s, averaging 87 percent from 1985 through 1990 brood years, and 44 percent from 1991 through 1998 brood years(personal communication with D. Simmons, NMFS, April 1, 2004). Canadian fisheries accounted for 39 percent of harvest mortality, Alaskan fisheries 2 percent, Puget Sound commercial and sport fisheries 50 percent, and Pacific coastal ocean fisheries 9 percent from 1991 through 1998 brood years.

The primary purpose of the hatchery program in the Skokomish River is fishery augmentation. The brood source is of mixed origin, with significant influence from transplants from South Puget Sound facilities. Under a policy adopted by the co-managers in 1991, all Puget Sound hatchery programs established using Green River stock were required to become self-sustaining, and transports of Green River-origin broodstock between watersheds were prohibited. The contribution of hatchery straying to natural spawning is unknown but believed to be substantial (PSIT and WDFW 2004; PSTRT 2003a; NMFS 2000a). Chinook supplementation program contributes to escapement on the Hamma Hamma River and straying from other hatchery programs within Hood Canal presumably occurs (personal communication with W. Beattie, NWIFC, January 31, 2004).

The **Strait of Juan de Fuca Region** has two watershed category 1 populations including a native, spring-timed population on the Dungeness, and a native, fall-timed population on the Elwha (PSTRT 2003a). Both populations are considered critical due to chronically low spawning escapement levels (WDF *et al.* 1993).

The Dungeness River is located in the rain shadow of the Olympic Mountains and, as a result, receives relatively little rainfall (less than 20 inches per year). The Dungeness is therefore particularly dependent on annual precipitation and snow pack, and is susceptible to habitat degradations that exacerbate low flow conditions. Agricultural water withdrawals remove as much as 60 percent of the natural flow during the critical low flow period which coincides with spawning. Other land use practices have also substantially degraded the system.

Much of the Elwha drainage is still pristine and protected in the Olympic National Forest. However, two dams at river miles 4.9 and 13.4 block passage to over 70 miles of potential habitat. The remaining habitat below the first dam is degraded by the loss of natural gravel, large woody debris, and the adverse effects of high water temperatures. The high temperatures exacerbate problems with the parasite *Dermocystidium* with resulting pre-spawning mortality is sometimes as high as 70 percent (WDF *et al.* 1993). Recovery of the Elwha population depends on restoring access to high quality habitat in the upper Elwha basin. The Elwha Dams are scheduled for removal beginning in 2007 thus greatly enhancing the prospects for eventually recovery of a viable chinook salmon population.

Dungeness escapement was below 250 spawners in all but three years between 1986 and 2001. Escapements averaged 345 adults from 1999 through 2002 (Table 2) compared with critical and viable thresholds of 200 and 925, respectively. The trend in escapement from 1986 to the present has been relatively flat, although there has been a marked increase in escapement since 2000. Elwha escapements averaged 2,009 from 1999 through 2002 (PSTRT 2003b) compared with critical and viable thresholds of 200 and 2,900 (Table 2). Although the long term trend has been downward, escapement levels have been stable since 1992.

Coded-wire tag data for these two populations from 1991 through 1996, indicate British Columbia fisheries accounted for 54 percent of the total harvest mortality, Alaskan fisheries 10 percent, Washington recreational fisheries 21 percent, Washington troll fisheries 5 percent, and Puget Sound net fisheries 9 percent (PSC data cited in NMFS 2000a). Exploitation rates on these populations have declined by 59 percent on average, from 76 percent in the 1980s to 31 percent in recent years (FRAM 2003).

Because of the limitations on natural production and low abundance, hatchery supplementation programs were initiated on both the Elwha and Dungeness using endemic broodstocks. Hatchery fish from the supplementation programs were included in the ESA listing because they were considered essential for recovery. Considering the current level of degradation in habitat quality and quantity, the populations would likely have gone extinct without the continued contribution of the hatchery programs. The contribution of hatchery straying to natural spawning is unknown but believed to be substantial (PSTRT 2003a; and NMFS 2000b).

Viable Risk Assessment Procedure

NOAA Fisheries analyzes the affects of harvest actions on populations using quantitative analyses where possible and more qualitative considerations where necessary. The Viable Risk Assessment Procedure (VRAP) is an example of a risk assessment that was developed by NOAA Fisheries, and applied so far primarily for analyzing harvest actions in Puget Sound. The Viable Risk Assessment Procedure provides estimates of population-specific exploitation rates (called Rebuilding Exploitation Rates or RERs). Proposed fisheries are then evaluated, in part, by comparing the RERs to rates that can be anticipated as a result of the proposed harvest plan. Where impacts of the proposed plan are less than or equal to the RERs, NOAA Fisheries considers the harvest plan to present a low risk to that population. The results of this comparison, together with more qualitative considerations for populations where RERs cannot be calculated, are then used in making the jeopardy determination for the ESU as a whole.

The kinds of qualitative considerations used for jeopardy determinations were discussed earlier in the Introductory section of this report. This section is a summary of the Viable Risk Assessment Procedure. A more detailed discussion of the risk assessment procedure can be find in an earlier NMFS report (NMFS 2000b). Following this section is a summary of how NOAA Fisheries used the available information to assess the affects of the 2004 proposed harvest regime on the Puget Sound chinook ESU.

The Viable Risk Assessment Procedure:

- quantifies the risk to survival and recovery of individual populations,
- accounts for total fishing mortality throughout the migratory range of the ESU,
- explicitly incorporates management, data, and environmental uncertainty, and
- isolates the effect of harvest from mortality that occurs in the habitat and hatchery sectors.

The result of applying the Viable Risk Assessment Procedure to an individual population is an Rebuilding Exploitation Rate (RER) which is the highest allowable ("ceiling") exploitation rate that satisfies specified risk criteria related to survival and recovery. In general, the Viable Risk Assessment Procedure is designed to provide an exploitation rate that will not appreciably reduce abundance to a level that will endanger its survival, and also will not impede the opportunity for the population to recover.

NMFS must evaluate the proposed harvest actions by examining the impacts of harvest within the current context. Therefore, NMFS has evaluated the future performance of populations in the ESU under recent productivity conditions; i.e., assuming that the impact of hatchery and habitat management actions remain as they are now. The actual performance of the populations will vary due natural variability in freshwater and marine survival, and may also vary due to actions in the habitat and hatchery sectors. For example, if habitat and hatchery actions improve conditions over currently existing conditions, the current NMFS conservation standards would be conservative, likely overestimating the impact that harvest actions would have on the ESU. As new information becomes available the RERs will be revised.

There are four steps involved with determining population specific RERs: 1) determine the spawner-recruit relationship, 2) set critical and rebuilding escapement thresholds, 3) define risk criteria, and 4) identify, through simulation, the appropriate RER.

Determine Spawner-recruit Relationship

The first step is to use recent data from the target population, or a representative indicator population, to fit a spawner-recruit relationship that represents the performance of the population under current conditions. This is used to predict the behavior of the population in future years under different harvest levels. Population performance is modeled as

$$R = f(S,\mathbf{e}),$$

where S is the number of fish spawning in a single return year, R is the number of natural-origin recruits[3], and **e** is a vector of environmental, density-independent correlates of annual survival.

Several data sources are necessary for the analysis including age-specific time series of natural spawning escapement and total fishing related-mortality, the proportion of hatchery-origin spawners in the escapement, and time series for the environmental correlates of survival. It is then necessary to assume a functional form for the spawner-recruit relationship. The simulation model is flexible with respect to the spawner-recruit function used. The model currently allows the user to choose among several different variations of the Ricker model, a linear or "hockey-stick" model, or a Beverton-Holt model. So far,

[3] Equivalently, this could be termed "potential spawners" because it represents the number of fish that would return to spawn absent harvest-related mortality. Natural-origin recruits are those whose parents spawned in the wild.

parameters have been estimated using methods developed by the Chinook Technical Committee and applied on a coast-wide basis (CTC 1999). Equations for the three models are as follows:

$(\mathbf{R} = \mathbf{a}\mathbf{S}e^{-bs})(\mathbf{M}^{c}e^{df})$ [Ricker]

$(\mathbf{R} = \mathbf{S}/[\mathbf{b}\mathbf{S} + \mathbf{a}])(\mathbf{M}^{c}e^{df})$ [Beverton-Holt]

$(\mathbf{R} = \mathit{min}[\mathbf{a}\mathbf{S},\mathbf{b}])(\mathbf{M}^{c}e^{df})$ [hockey stick]

In the above equations, M is the index of marine survival and F is the freshwater correlate.

<u>Set Critical and Viable escapement Thresholds</u>

The Viable Salmonid Population paper (McElhaney *et al.* 2000) identifies threshold abundance levels as one of several indicators of population status. The thresholds described include a critical threshold and a viable threshold. The critical abundance threshold generally represents a boundary "...below which populations are at relatively high risk of extinction in the near future." The VSP paper defines the viable escapement threshold as a higher abundance level "...above which populations have negligible risk of extinction due to local factors."[4] (McElhaney *et al.* 2000). The Viable Salmonid Population document does not provide specific guidance, but does provide rules of thumb, for setting either critical or viable escapement thresholds (McElhaney *et al.* 2000). Because the thresholds are needed to determine the RERs, NOAA Fisheries used the VSP recommendations, information from existing scientific literature, and population-specific information, to make preliminary threshold determinations for Puget Sound chinook populations. The preferred approach was always to use population-specific data where sufficient.

Critical Abundance Threshold

Three methods were used to derive the critical abundance thresholds based on a consideration of genetic, demographic, and spatial risk factors, and the quality of available data for each population. Genetic risks to small populations include the loss of genetic variation, inbreeding depression, and the accumulation of deleterious mutations. The risk posed to a population by genetic factors is often expressed relative to the effective population size (N_e), which is the size of an idealized population for an entire generation that would produce the same level of inbreeding or genetic drift that is seen in an observed population. Effective population size N_e can be converted approximately to effective number of breeders in a single year (N_b) by dividing N_e by generation length. N_b is equivalent to annual spawning abundance which is the metric that is typically available for salmon populations.

The literature suggests that effective population sizes of less than 167-1,667 per generation (N_b = 50-500) are at high to very high risk (Allendorf *et al.* 1997). The population size range per generation for chinook was converted to an annual spawner abundance range of 42-417 by dividing by four, the approximate generation length of Puget Sound chinook. An escapement level of 200 fish was selected from this range to represent a critical threshold for genetic risk factors (method 1) since most of the populations that were subject to the RER analysis are relatively small (i.e., habitat capacities of several hundred to several thousand fish).

The Biological Requirements Work Group (BRWG 1994) took genetic considerations and other factors into account in their effort to provide recovery guidance with respect to a lower population threshold for Snake River spring/summer chinook. They recommended that annual escapements of 150 and 300, for

[4] with the caveat that abundance is not the only relevant or necessary indicator of recovery

small and large populations, represented levels below which survival becomes increasingly uncertain due to various risk factors and a lack of information regarding population responses at low spawning levels. This provides independent support for the use of 200 (within the range of 150-300) as a critical threshold.

Methods 2 and 3 were based on factors associated with demographic risks including environmental variability and depensation. Depensation, or a decline in the productivity of a population (e.g., smolts per spawner) as the abundance declines, can result from the uncertainty of finding a mate in a sparse population, increased predation rates at low abundance, or as a result of poor nutrient conditions associated with low escapement. Demographic risks were assessed using a Ricker stock-recruit model and available productivity patterns. For method 2, Peterman (1977, 1987) provided a rationale for depensation and suggested relating the escapement level at which depensation occurs to the size of the population in the absence of fishing (equilibrium escapement level). Based on Peterman's work, NOAA Fisheries set this measure of the critical threshold equal to 5% of the equilibrium escapement level. The final alternative (method 3) was to use the lowest observed spawning escapement with a positive recruitment. That is, the number of progeny relative to parental spawners was greater than one.

For each population the three methods for identifying a critical abundance threshold were considered in the context of the types and quality of data available, the characteristics of the watershed, and the biology of the population. For "large populations," NOAA Fisheries generally selected a critical threshold based on method 2 to assure a sufficient density of spawners. Methods 1 and 3 were used for smaller populations, populations for which NOAA Fisheries was unable to estimate the equilibrium population size, or where the result of method 2 was inconsistent with what was known about the distribution and amount of available spawning habitat.

Viable escapement Threshold

Two methods were used to establish viable escapement thresholds, also referred to as rebuilding thresholds. These also relied on genetic, demographic and spatial risk factor considerations. Method 1 uses estimates of maximum sustain yield (MSY) escapement. The VSP guidance states, "...a wild population harvested at MSY is, by definition, sustainable (VSP) - provided that the time horizon of MSY is the same as VSP and the MSY estimate takes into account all the factors affecting viability, such as genetic diversity and spatial structure."

Method 2 was derived based on guidance from the scientific literature and used for populations for which NOAA Fisheries was unable to estimate the equilibrium population size, or where the result of method 1 was inconsistent with what was known about the distribution and amount of available spawning habitat. McElhaney et al. (2000) provide a guideline of 1,670 -16,700 spawners per generation based on genetic considerations (referencing Franklin 1980, Soule 1980;, and Lande 1995). McElhaney et al. (2000) also suggest a range of 1,000-10,000 spawners per generation to account for environmental variability (referencing Belovsky 1987, Goodman 1987, and Thomas 1990). These ranges are divided by 4 years, the approximate average generation length of chinook, to provide a viable threshold that is expressed in terms of annual spawning abundance. These considerations provided an alternative rebuilding threshold of 1,250.

By definition, generic thresholds offer only general guidance as to what generally represents points of stability or instability. Some populations may be fairly robust at very low abundances, while chinook salmon populations in large river systems may become unstable at higher abundances depending on resource location and spawner density. However, without population-specific information, NOAA Fisheries believes these generic guidelines offer the best available information. The choice of method for a population again depended on the types and quality of available data available, the characteristics of the watershed, and the biology of the population.

It is appropriate to emphasize that decisions regarding the viability thresholds are not necessarily final. The estimates are based on available information and current conditions. Periodic review of threshold determinations, or other parameters used in the risk assessment, are anticipated to ensure they remain consistent with best available information. For most populations, these thresholds are well below the escapement levels associated with recovery, but achieving these goals under current conditions is a necessary step to eventual recovery when habitat and other conditions are more favorable.

Define Risk Criteria

The next step is to define the necessary risk criteria and the time frame for the analysis. Unlike the technical exercise used to derive the spawner-recruit relationship and the abundance thresholds, the amount of risk, and the duration over which it is measured, are largely a policy decisions.

To calculate the RER it is necessary to specify the probability that a population will survive (i.e., stay above the critical abundance threshold) and recover (i.e., exceed the rebuilding threshold). These were chosen based on a review of past NOAA Fisheries decisions and common scientific standards. The associated rationale is described in more detail in an earlier report on the risk assessment procedure (NMFS 2000b).

An RER establishes a standard for total fishing-related mortality for a population. The baseline against which the RER is derived is therefore no harvest of the population anywhere in its migration range. The risk criteria for calculating RERs, are that 1) the percentage of escapements below the critical threshold differs by no more than 5% from the no harvest scenario; and, 2) the rebuilding threshold must be met at least 80% of the time, or the percentage of escapements less than the rebuilding threshold differs by no more than 10% from the no harvest scenario.

In order to do the RER simulation it is also necessary to define a time frame over which risk is measured. Based on a review of past decisions and relevant information, NOAA Fisheries chose 25 years as the time frame for evaluating the risk criteria. In doing this, we assumed model assumptions would be evaluated every 5-10 years and the RERs adjusted as necessary to respond to changing resource and environmental conditions.

Identify Population Specific Rebuilding Exploitation Rate

The final step in the Viable Risk Assessment Procedure is to use a simulation model to iteratively solve for the RER. The RER is the highest exploitation rate that meets criterion 1 and criterion 2 described in step 3 (Figure 4). Probabilities of survival and rebuilding are calculated for a series of target exploitation rates in a stepwise fashion, starting at 0% (which provides the 0 harvest baseline) and proceeding to 80% in steps of 1%. For each target exploitation rate, the model simulates 1000 25-year projections[5]. Estimated probabilities of exceeding the rebuilding abundance escapement threshold are based on the number of

[5]The number of iterations and years over which the model is run are defined by the user.

simulations for which the average of the spawning escapements in the last five years exceed the rebuilding threshold. Estimated probabilities of falling below the critical threshold were based on the number of years (out of the total of 25,000 individual years projected for each target exploitation rate) that the spawning escapement falls below the critical threshold. Each repetition starts with an initial population size. The initial population size will influence the risk assessment of falling below the critical threshold or above the rebuilding threshold, so it should represent the current population status. Within a year, natural mortality is applied first before any fishing mortality or maturation. Management error is applied as a multiplicative factor to the target exploitation rate. Escapement is calculated for both total escapement and total adult escapement. For the next year, the cohort advances to the next age and new recruitment is calculated from the previous year's escapement (NMFS 2000b).

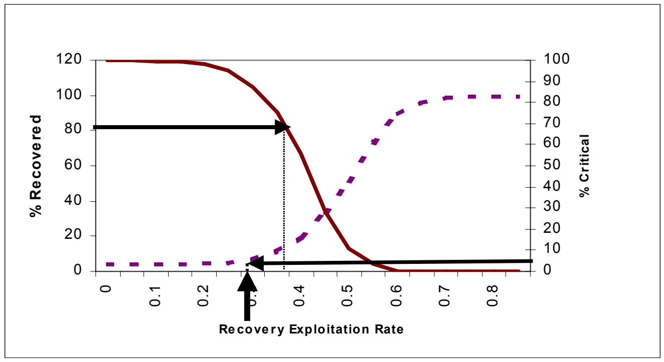

Figure 4. Example of the derivation of an recovery exploitation rate.

The simulation model incorporates available information on management error, and errors in measurement of the stock recruit parameters used in the model to account for uncertainty in management precision and parameter estimation, and variability in the environmental parameters that affect the survival of the population. Management error (the difference between target and actual exploitation rate) accounts for variability in expected abundance, regulatory effects and expected fishing effort. It is derived by comparing exploitation rates estimated to have actually occurred with the exploitation rates that harvest managers anticipated would occur prior to the beginning of the fishing season. Management error was based on five representative Puget Sound populations for the years 1988-1993 (Gutmann 1998). The percent error (actual vs target) varied from –25% to +51.0% for Puget Sound chinook populations (NMFS 2000b).

Error in the estimation of spawner-recruit parameters is calculated from the difference between the values of predicted and observed escapements during the derivation of the spawner-recruit relationship. It accounts for errors in escapement sampling (sex ratio and age distribution and spawner counts), and estimates of fishing-related mortality and survival.

Variability in environmental factors is needed to project the pattern of population abundance into the future. The more variable the environment, the more variable will be the population survival and abundance. Population survival and abundance tends to be higher during periods of good

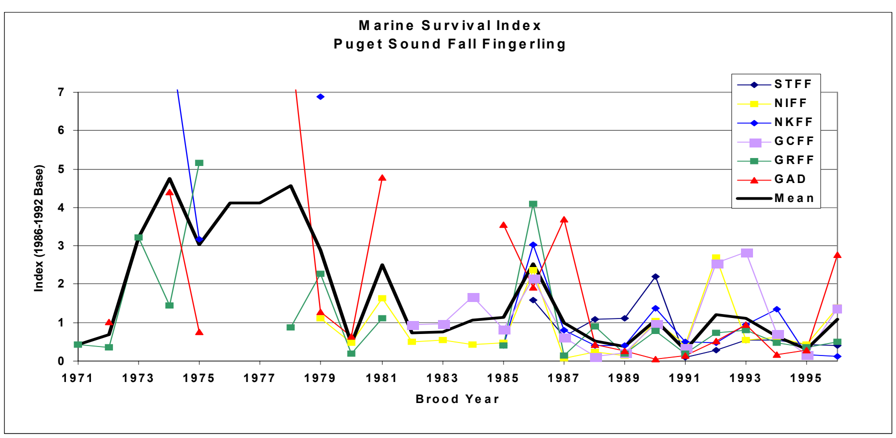

Figure 5. Marine survival is generally similar across Puget Sound chinook stocks. Survival in the 1990s is substantially lower than that in the 1970s.

environmental conditions and lower during periods of poor environmental conditions. The variability in the environmental factors (marine and freshwater survival) is derived from the mean and variance of the annual estimated marine survival for a particular population or group of populations during a specific time period. In general marine survival was high for 1973-1979 broods and low for 1983 to current broods (Figure 5). We use marine survivals from the generally low survival period because marine conditions is such an important factor in Puget Sound chinook survival and because we have been in a period of low marine survival. Climatic conditions tend to occur in cycles of approximately 20-30 years and we are unsure where we are in that cycle. Although there are some indications that ocean conditions may be improving, we have not confirmed this in Puget Sound. Freshwater patterns were much more variable and do not show the cyclic patterns known to occur in marine waters, so the variability in freshwater environmental variables is drawn from the brood years used in the spawner-recruit analysis.

In summary, the rebuilding exploitation rate (RER) is the highest allowable ("ceiling") exploitation rate that, compared to a hypothetical situation of zero harvest impact, will not appreciably reduce populations below critical abundance levels, or impede the opportunity for the population to rebuild towards recovery given current environmental conditions. Monitoring of annual escapements will provide information on the temporal and spatial distribution of spawners and an evaluation of the model's predictions, i.e., are escapements occurring above or below the thresholds at the frequency that the model predicted? The RERs will be reviewed periodically and revised if necessary to incorporate the new information.

RER Estimation Example - Skykomish River Chinook

The Skykomish RER was based on analyses of the 1979-1996 brood years. Uncertainty about accuracy of escapement data and completeness of catch data precluded use of data before 1979. The 1996 brood year (returning in years 1998-2001) was the last year for which data were available at the time to conduct a complete cohort reconstruction. Before completing the spawner-recruit analysis and RER derivation it was necessary to address uncertainties related to estimates of fishing related mortality, maturation rates, and the effectiveness of hatchery spawners. These are typical of the kinds of data issues that must be resolved in preparing the data for analysis.

Estimates of fishing-related mortality

Escapement data is expanded by estimates of fishing-related mortality[6] and natural survival to estimate total recruitment. Pre-terminal fishery rates were based on an aggregate of Puget Sound summer/fall chinook hatchery indicator population populations (Stillaguamish, Green, Grovers, George Adams, Nisqually, Samish). There is currently no hatchery stock to represent the Snohomish populations and no direct measure of fishery exploitation on the wild populations. We evaluated two options for estimating fishing mortality on the Snohomish populations: 1) an aggregate of Puget Sound summer/fall chinook hatchery coded-wire-tag (CWT) indicator populations using the Pacific Salmon Commission Chinook Technical Committee (CTC) exploitation rate analysis; and, 2) estimates of mortality on Snohomish chinook from the CTC chinook model. Option 1 uses CWT recoveries from individual years to reconstruct the mortality for that year, but is dependent on a consistently high rate of catch and escapement sampling to make precise estimates. Also, it is possible that the Snohomish populations may not have the same distribution as the populations within the aggregate. Under Option 2, the CTC model uses CWT recoveries from the Stillaguamish indicator stock, a summer chinook population in an adjacent drainage, during the 1979-1982 base period to estimate fishery mortality on the Snohomish population in subsequent years so estimates are less subject to year-year variability in sampling rates. Several of the managers also

[6]Fishing-related mortality includes both catch and mortality that occurs as a result of fishing activities, i.e.., fish that die as a result of encounters with fishing gear but are not landed by the fisherman.

felt the CTC model estimates better reflected the pattern of reduced overall exploitation they expected to see in the early 1990's resulting from more restrictive fishing regimes. As with Option 1, it is possible that the distribution and exploitation of the Stillaguamish and Snohomish populations are different.

After further evaluation, Option 1 was chosen because we determined that, for the purposes of deriving an RER, year specific fishery rates over the range of years in the data period would be better than estimates derived from a base period based on a limited number of Stillaguamish CWT recoveries. Option 1, by using an aggregate set of populations, maximizes the use of the available data and smooths differences in any one year associated with a particular population. Also, we were able to address most of the concerns we had with Option 1. Puget Sound summer/fall chinook populations, in fact, show similar patterns of exploitation in preterminal fisheries, so one could reasonably expect the Snohomish summer/fall populations to follow a similar pattern. In addition, catch and escapement sampling for most of the populations within the aggregate meet or exceed their target sampling rates in most years. Therefore, the Puget Sound summer/fall chinook aggregate was used as a surrogate to represent the Snohomish populations in preterminal fisheries.

“Terminal” area fisheries affecting Skykomish summer-run chinook include mature chinook harvested in net fisheries throughout Puget Sound and in recreational fisheries in the Snohomish River system and immediately adjacent marine area. The fishery harvest is partitioned into natural and hatchery-produced components based on the relative magnitudes of the escapement to natural areas and to the Wallace River Hatchery, relative run strength in the river and adjacent marine areas and the results of recoveries of thermally-marked otoliths from the Tulalip hatchery. The otolith recoveries are used to estimate the Tulalip hatchery contribution to this fishery for the brood years from 1997 to present (Rawson *et al.* 2001), which is subtracted from the total catch. The terminal fishing mortality is then the total harvest of mature fish divided by the catch plus the Snohomish natural escapement.

Maturation Rates
Maturation rates are used in VRAP to project future escapements, i.e., what proportion of the recruits will mature and return to spawn at a given age. We also considered two options for the maturation rates (the fraction of each cohort): 1) maturation rates derived from age data collected from scales and otoliths from the spawning grounds combined with the age-specific fishing rates described above; 2) estimates derived from the CTC model for the Snohomish model population. In general, fish matured at older ages under Option 1 than Option 2, and no fish matured as two year olds. We decided to use Option 1 because it is a more direct measure of the age structure of the spawners.

However, we identified two potential concerns that should be taken into account when using the data: 1) age 2 fish are generally under represented in spawning ground samples for several reasons: e.g., carcasses decay faster, the smaller body size makes them more susceptible to being washed downstream, they are less visible to samplers; and 2) only one year, 1989, had a sufficient number of samples to use. The age structure for other years was extrapolated from 1989 by using the 1989 age composition to reconstruct brood year and calendar year escapements by age. The age structure is then adjusted to minimize the difference between the estimated calendar year escapements and the observed calendar year escapements for each year for which data are not available.

Hatchery Effectiveness
Hatchery spawners contribute significantly to escapement of naturally spawning Skykomish adults in some years. Their effectiveness in spawning may effect the productivity of the population. If they are as effective as the wild fish and we assumed that they were not, then we would overestimate the ability of the

wild spawners to replace themselves since the hatchery spawners are contributing equally to the subsequent generation. If they are not as effective, then we would underestimate the productivity of the wild spawners. For the Skykomish River, no adjustments were made for the relative fecundity of naturally-spawning hatchery-produced fish as compared with natural-origin fish, since there is no available data for the effectiveness of hatchery spawners in the wild when compared with their natural origin counterparts for Puget Sound chinook. For the RER analysis, we assumed all spawners contributed equally regardless of their origin. This is a conservative assumption since it will tend to underestimate productivity and therefore the resulting RER, minimizing the possibility of adopting a harvest objective that was too high (Table 5.)

Table 5. Intrinsic Productivity (MSY Exploitation Rate) by Production Function for the Skykomish chinook population

Hatchery Effectiveness	Ricker	Beverton-Holt	Hockey Stick
Hatchery not Effective	7.58 (49%)	14.14 (65%)	8.07 (77%)
Hatchery Half as Effective	6.26 (52%)	8.34 (65%)	4.55 (63%)
Equal Effectiveness	5.49 (47%)	6.51 (53%)	3.66 (51%)

Spawner-Recruit Relationship
The population data were fit using three different models for the spawner recruit relationship: the Ricker (Ricker 1975), Beverton-Holt (Ricker 1975), and hockey stick (Barrowman and Myers 2000). The simple forms of these models were augmented by the inclusion of environmental variables correlated with brood year survival (marine survival and freshwater flow during adult spawning and egg incubation).

Abundance Thresholds
The critical escapement threshold was set at 1,650 natural origin spawners based on the smallest observed escapement returned greater than one progeny per spawner, and a generally increasing escapement trend since 1990. Estimated natural origin escapement since 1990 was generally higher (range = 942-3,052) than what would be considered critical based on our general guidance. The 1990-2002 median total escapement to the spawning grounds, including hatchery strays, was 2,932 (2,018 of natural origin).

The rebuilding escapement threshold was the MSY escapement level which varies with particular form of the spawner-recruit relationship. These values were: 3,500 - Ricker, 3,600 - Beverton-Holt, and 3,600 - hockey stock. Since no one form performed statistically better than the others, the average of the values (3,550) was used as the rebuilding threshold.

RER Derivation
We projected the performance of the Skykomish population at exploitation rates in the range of 0 to 0.30, in increments of 0.01 using the parameters for each of the three spawner-recruit models. For each combination of spawner-recruit relationship and exploitation rate we ran 1000 25-year projections. Summarized results of these projections are in Table 6, and detailed results are in Table 7. RERs under each spawner-recruit function were estimated as 0.25 – Ricker, 0.27 – Beverton-Holt, and 0.22 – hockey stick. Since there was no basis to choose one of these models over the other, we used the average of these values as the target exploitation rate. This average is 0.24, rounding down to the nearest whole percentage exploitation rate.

Table 6. Results of the VRAP projections of the Skykomish chinook population under current conditions showing the indicated target exploitation rate for each form of the spawner-recruit relationship.

Model	Target Expl. Rt.	#fish Mort.	%runs extinct	%yrs <critical	%runs >rebuilding	1st Year Escape	LastYrs Ave. Escape
Ricker	0.25	1671	0	4.0	80.0	2123	5711
Beverton-Holt	0.27	1889	0	4.5	80.3	2084	6149
Hockey-Stick	0.22	1427	0	3.0	81.3	2172	5747

Table 7. Summary of projections of the Skykomish population at different target exploitation rates for three different forms of the spawner-recruit relationship. The target exploitation rates at which the criteria are met are indicated in bold.

	Prob(final esc. <rebuilding)%				Prob(ann.Esc. <critical)%		
Target ER	B-H	Ricker	Hockey-Stick		B-H	Ricker	Hockey-Stick
0.00	99.20	96.60	96.30		0.30	0.50	0.50
0.01	99.40	97.80	96.50		0.40	0.70	0.60
0.02	99.00	96.40	95.80		0.50	0.70	0.60
0.03	98.70	95.80	95.60		0.40	0.60	0.50
0.04	98.10	95.60	94.70		0.40	0.70	0.60
0.05	98.40	96.40	95.80		0.50	0.70	0.70
0.06	97.80	95.10	94.30		0.60	0.90	0.80
0.07	97.40	94.70	93.20		0.60	0.90	0.80
0.08	97.80	94.90	94.00		0.60	0.90	0.80
0.09	97.50	94.80	93.70		0.70	1.00	1.00
0.10	97.40	94.20	92.70		0.70	1.00	1.00
0.11	96.90	94.10	92.20		0.90	1.20	1.10
0.12	95.70	92.10	90.50		0.80	1.20	1.20
0.13	96.50	93.40	90.70		1.20	1.60	1.60
0.14	96.00	92.10	90.30		1.10	1.40	1.40
0.15	95.60	90.40	89.30		1.20	1.50	1.60
0.16	93.60	90.90	88.20		1.60	2.00	2.00
0.17	93.70	89.80	87.00		1.50	1.80	2.00
0.18	91.40	87.90	84.60		1.60	1.90	2.10
0.19	91.10	87.70	83.80		2.10	2.50	2.80
0.20	91.00	86.90	83.90		1.90	2.30	2.60
0.21	91.00	87.90	84.40		2.10	2.40	2.80
0.22	90.70	87.30	**82.50**		2.30	2.70	3.00
0.23	86.40	82.70	78.70		2.80	3.20	3.70
0.24	86.40	82.30	77.10		3.40	3.70	4.40
0.25	84.30	**80.00**	75.30		3.50	4.00	4.80
0.26	85.80	82.40	76.90		3.30	3.90	**4.70**
0.27	**80.30**	77.10	71.50		4.50	**4.90**	6.10
0.28	77.90	73.90	68.70		**4.50**	5.00	6.30
0.29	78.40	73.90	65.80		5.10	5.60	7.20
0.30	75.20	72.00	65.60		5.20	5.60	7.50

Puget Sound Chinook Population Assessment

In reviewing the proposed fishery plan, NOAA Fisheries considered, in particular, the environmental baseline, the status of each population, and the effect of the 2004 fishery plan on that status (NMFS 2004). Preseason modeling of the proposed fisheries provided estimates of population specific exploitation rates and/or escapements. For those populations with associated RERs, the proposed fisheries were evaluated primarily by comparing the expected exploitation rates with the population-specific RERs. For populations that met their RERs, NOAA Fisheries concluded that the fishery plan was not likely to impede the ability of the population to survive or recover. For those populations for which we do not yet have RERs, we relied on more qualitative information, including expected escapements and exploitation rates in 2004, escapement trends relative to critical and viable thresholds, past fishery performance, the positive and negative consequences of hatchery programs, and similarity of life history and genetic characteristics with other populations within the same region and within the ESU. While the initial analysis was made with respect to populations, the jeopardy determination considered the effect on the ESU as a whole. The failure to meet the RER standard for one population in an ESU with multiple populations, does not necessarily indicate jeopardy to the ESU. In the following discussion, we summarize NOAA Fisheries' conclusions regarding the relative risk to each population resulting from the proposed 2004 fishery plan. The determination regarding the ESU is then made by considering the distribution of risk as determined by those individual population assessments across the ESU.

Strait of Georgia: There are two populations within the Strait of Georgia Strait: the North Fork Nooksack River and the South Fork Nooksack River early Chinook salmon populations. Both are classified as Category 1 populations. Straying between the two populations was historically low, as supported by available genetic data, but straying may have increased in recent years (PSTRT 2003a). Average escapement for both populations in this region increased in recent years over pre-listing levels, although natural-origin escapement for both populations remain close to their critical escapement thresholds; and therefore, remain a cause for concern. Using the recent year average escapement distribution, escapement in 2004 was expected to be 234 and 336 for the North Fork and South Fork Nooksack early Chinook populations, respectively and 570 for the Nooksack early Chinook Management Unit. Escapements in 2004 were anticipated to be above the recent year average escapements, above their respective critical escapement thresholds and above the viable escapement threshold for the management unit. If naturally spawning hatchery-origin adults from the listed supplementation program were included, early Chinook salmon escapement averaged 3,400 in the North Fork Nooksack in recent years, a 1000 percent increase since listing. Over the same period, natural-origin spawning chinook adults increased by only 11 percent.

When compared to hatchery-origin returns, the lack of a similar dramatic increase in natural-origin fish, given the substantial decreased in harvest rates over the same time, suggests natural-origin recruitment will not increase much beyond existing levels unless constraints limiting marine, freshwater, and estuary survival are alleviated. Augmentation of natural-origin spawners on the natural spawning areas of the North Fork Nooksack River, with the addition of hatchery-origin spawners, will continue to test the natural production potential of the system at higher escapement levels. The broodstock used for the Kendall Creek Hatchery program, located on the North Fork Nooksack River, retains the genetic characteristics of the original, donor, wild population and is considered essential for the survival and recovery of the ESU. Therefore, adult fish produced by the Kendall Creek Hatchery program and migrating with the natural-origin fish may buffer harvest-induced genetic and demographic risks to the natural-origin North Fork Nooksack River population.

The total exploitation rate on both populations declined by 45 percent since the 1980's, averaging 74 percent from 1981 through 1984, and 41 percent for 1991 through 1998 brood years (personal communication with D. Simmons, NMFS, April 1, 2004). The expected exploitation rate in 2004 in southern U.S. fisheries (6%), including Puget Sound fisheries, was well below the RER for the Nooksack early management unit, but the total ocean exploitation rate was expected to exceed the RER (Table 8). However, the RER for the Nooksack early management unit was not expected to be met in 2004, even with total closure of all southern U.S. fisheries. Natural origin escapement has increased since the ESU was listed and, in 2004, the Nooksack spring natural origin escapement was expected to exceed its viable escapement threshold.

Similar to recent years, the majority of southern U.S. fishery harvest impacts on the Nooksack Management Unit populations in 2004 (74%) were expected to occur in treaty Indian fisheries. Since 2001, on average, 77 percent of the southern U.S. harvest on the Nooksack Management Unit occurred in tribal fisheries. In recognition of tribal management authority and the Federal government's trust responsibility to the tribes, NOAA Fisheries is committed to considering their judgment and expertise regarding the conservation of trust resources. Consistent with this commitment and as a matter of policy, NOAA Fisheries has sought where there is appropriate tribal management, to work with tribal managers to provide limited tribal fishery opportunities, so long as the risk to the population remains within acceptable limits.

Whidbey/Main Basin: The largest river systems in Puget Sound are found within the North Puget Sound Region. The ten chinook salmon populations in this region are all Category 1 populations. Average escapements for eight of the ten populations in this region had increased above pre-listing levels and the other two were stable. Five of the ten populations in this region, including both spring and summer/fall life history types, were currently above their viable escapement thresholds, two were approaching their viable escapement threshold and one was below its viable threshold but well above its critical escapement threshold (Table 9). Data at the time was not sufficient to derive viable thresholds for the Upper Cascade River in the Skagit spring management unit or the Snoqualmie River population in the Snohomish management unit. However, both populations were above their critical escapement thresholds (Table 9). Escapements in 2004 were expected to exceed recent year average escapements for nine of the ten populations, and exceed viable escapement thresholds for all eight populations for which they had been derived.

Exploitation rates had fallen 43 to 49 percent from levels in excess of 60 percent during the mid-1980s, to an average in recent years of 23 to 42 percent depending on the population (FRAM 2003; personal communication with D. Simmons, NMFS, April 1, 2004). NOAA Fisheries determined that the proposed 2004 fisheries would meet RERs for eight of the ten populations (80 percent) within this region (Table 8). The total exploitation rate for the Snohomish management unit was expected to exceed its RER in 2004, primarily due to harvest in Canadian fisheries. However, natural-origin escapement in the Skykomish River had exhibited an increasing escapement trend since listing and was expected to exceed its viable escapement threshold in 2004. In fact, the expected escapement in 2004, if realized, would be the highest in the database to that time.

Southern Basin: There are six populations delineated by the PSTRT within the South Puget Sound Region. In this region, the Cedar and Duwamish-Green River fall chinook salmon populations and White River spring chinook salmon population are Category 1 populations. The Sammamish, Puyallup and Nisqually River chinook are Category 2 populations[7]. Genetically, most of the present spawning aggregations in the South Puget Sound Region are similar, likely reflecting the extensive influence of transplanted stock hatchery releases, primarily from the Green River population (PSTRT 2003a). The fall chinook salmon

[7]Category 2 watersheds are areas where indigenous populations are believed to no longer exist, but where sustainable wild populations existed historically and wild production is self-sustaining at present.

populations in the South Puget Sound Region also share similar life history traits. The Puyallup and Nisqually systems were managed for hatchery harvest rates for decades. Beginning in 2000, management transitioned in the Nisqually and Puyallup systems from a focus on hatchery management to management objectives based on naturally spawning adults. Average escapements for four (both spring and fall types) of the six populations in this region were above pre-listing levels (Sammamish, Duwamish-Green, White, Nisqually) and both long and short term trends in escapement for all populations had generally been positive. Escapements for four of the six populations in this region had exceeded viable escapement thresholds in recent years (Duwamish-Green, White, Puyallup, Nisqually) and were expected to do so again in 2004 (Table 9).

The proposed Puget Sound fisheries in 2004 were anticipated to contribute to the stabilization or rebuilding of all populations within this region[8]. However, NOAA Fisheries had identified a concern for two South Puget Sound Region populations (Cedar River and Sammamish River) due primarily to anticipated low abundance and the level of volatility observed in past escapements. Escapements for both the Cedar and Sammamish chinook populations had exceeded their critical thresholds since 1998, but were well below their viable thresholds (Table 9). Escapement to the Cedar was considered stable while escapement to the Sammamish was increasing. However, since the escapements estimates were based on partial census of the populations, the escapement estimates were considered conservative as the total escapements for these two systems were likely greater. Because both populations were affected by the same terminal fisheries, NOAA Fisheries expected that protective measures imposed to safeguard the Cedar River population would also incidentally benefit the Sammamish River population. Noteworthy limiting factors in the Lake Washington basin were being addressed by improving passage conditions for salmon at the Ballard Locks, in addition to recently restored anadromous fish access to 12 miles of the Cedar River. While these improvements will likely enhance spatial structure and productivity, there remain highly altered conditions in the Lake Washington basin and at the Ballard Locks that are daunting to juvenile emigration and adult immigration.

Past strategies to maximize harvest of hatchery stocks resulted in exploitation rates of 80 percent or more. Total exploitation rates had declined by 14 to 63 percent since the early 1980s, averaging 29 to 77 percent in recent years, depending on the population (FRAM 2003). The expected exploitation rate for the Duwamish-Green chinook population in 2004 Puget Sound salmon fisheries was expected to be 34 percent (Table 8), well below the RER of 53 percent, but, when added to the expected ocean exploitation rates, the projected 2004 total exploitation rate was expected to exceed the RER for the Duwamish-Green chinook population (63%). However, escapement in 2004 was expected to remain above the viable escapement threshold of 5,500 (Table 9).

Hood Canal: The Skokomish and Mid-Hood Canal Rivers populations are both Category 2 type populations. Average recent years escapement for both populations had increased above pre-listing levels (Table 2). The Skokomish River escapement had been near or above its viable escapement threshold in four of the last five years and was expected to exceed its viable threshold in 2004 (1,262 naturally spawning adults) (Table 9).

There was a potential concern for harvest impacts to the spatial structure of the Mid-Hood Canal Rivers population. This concern was heightened because of the low abundance in two of the individual tributaries.

[8]With the level of escapement for the Duwamish-Green River population anticipated to continue to exceed the NOAA Fisheries-derived viable threshold, the level of risk to this population associated with implementation of the proposed 2004 Puget Sound salmon fisheries is low. However, it should be noted that hatchery-origin adults are believed to contribute substantially to the naturally spawning adults.

The 1999 to 2002 average escapement of 404 fish for the Mid-Hood Canal Rivers population was above the critical escapement threshold of 200, but well below the viable escapement threshold of 1,250 fish (Table 9). The Mid-Hood Canal Rivers population had exhibited an increasing escapement trend since listing (Table 2). However, the expected escapement in 2004 was 298, relatively close to the critical escapement level and lower than the recent years' average.

The Mid-Hood Canal Rivers population includes spawning aggregations in the Hamma Hamma, Duckabush, and the Dosewallips Rivers. Escapement into the individual systems had varied, with the spawning aggregation in the Hamma Hamma River representing the majority of the total Mid-Hood Canal Rivers population abundance in recent years. Adult returns resulting from the Hamma Hamma River supplementation program, which relies partially on broodstock returning to the river, has contributed substantially to the Mid-Hood Canal Rivers population's increasing abundance trend. In 2002, the natural escapement of 95 spawners into the Mid-Hood Canal Management Unit fell well below the VSP guidance for a critical threshold of 200 fish for this population. Spawning aggregations below 40 fish were observed in recent years in the Duckabush and Dosewallips Rivers.

The overall exploitation rate for Hood Canal summer-fall Chinook salmon declined by 49 percent since the early 1990s, averaging 87 percent from 1985 through 1990 brood years, and 44 percent from 1991 through 1998 brood years (personal communication with D. Simmons, NMFS, April 1, 2004). The anticipated exploitation rates for the Skokomish salmon chinook population in 2004 were 33 percent in southern U.S. salmon fisheries and 52 percent overall. Canadian fisheries were anticipated to account for 37 percent of the salmon fishery related mortality in 2004 on the Skokomish chinook salmon Management Unit (FRAM 2004). The anticipated exploitation rates for the Mid-Hood Canal Management Unit in 2004 were 11 percent in southern U.S. salmon fisheries and 31 percent overall (Table 8). Canadian fisheries were anticipated to account for 61 percent of the salmon fishery-related mortality (FRAM 2004).

Since most harvest impacts to this population occur outside Hood Canal, it is difficult for the co-managers to impose differential terminal harvest regimes on the individual spawning aggregate components in order to adjust spawning distribution among the tributaries. Even with no Puget Sound fisheries, anticipated escapement into the Mid-Hood Canal Rivers population was expected to increase by an estimated 36 spawning adults, spread among the three component natural spawning rivers. Given the ratio of recent year escapements into the individual river systems in the Mid-Hood Canal Rivers population, escapement was expected to increase by 24, 5 and 7 adults for the Hamma Hamma, Duckabush and Dosewallips, respectively. Based on this modeling, there was little effect that further decreases in the proposed Puget Sound fisheries-related impacts would have on the persistence of the spawning aggregations in the Dosewallips and Duckabush Rivers. The co-managers had implemented additional conservation measures in pre-terminal and terminal fisheries to reduce mortality including non-retention, no directed fisheries, and reduction in incidental impacts in other fisheries by the use of time and area restrictions (PSIT and WDFW 2004).

The hatchery-origin production derived from broodstock returning to the Hamma Hamma River may buffer demographic risks to the Mid-Hood Canal tributaries population in the short term, particularly to the component of the population spawning in the Hamma Hamma River. The characteristics of the Mid-Hood Canal Rivers population, including life history and run timing, are also found in the Skokomish River population, the only other population within the region. Genetically similar stocks are also sustained by several hatchery facilities in the Hood Canal area and in hatcheries in the South Puget Sound Region where the Green River-linage are naturally or artificially sustained.

Strait of Juan de Fuca: There are two populations within this region: the Elwha, a fall timed population, and the Dungeness, a spring timed population. Both are classified as Category 1 populations. Recent years' average escapement for the Dungeness population was above pre-listing levels and above its critical escapement threshold, although well below its viable escapement threshold. The Elwha Chinook population was considered stable with a post-listing average escapement of 2,000 compared with a viable escapement threshold of 2,900 adults. Escapements in 2004 were expected to be 461 and 2,310 for the Dungeness and Elwha populations, respectively (Table 9). Both expected escapements were above recent years' averages.

Exploitation rates had declined by 59 percent on average, from 76 percent in the 1980s to 31 percent in recent years (FRAM 2003). The expected exploitation rate in 2004 Puget Sound salmon fisheries was 4 percent with a total exploitation rates (including Alaskan and Canadian fisheries) of 24 percent. Anticipated southern U.S. exploitation rates were low (5%) and further reductions were expected to have little practical effect on the persistence of these two populations. Canadian fisheries were anticipated to account for 69 percent of the total exploitation rate on the Dungeness and Elwha populations in 2004 (NMFS 2004).

The hatchery-origin production operating in the two watersheds within this region share the ecological and genetic traits of the natural-origin populations and is considered essential to recovery of the ESU. Considering the current level of degradation in habitat quality and quantity, the populations would likely have gone extinct without the continued contribution of the hatchery programs.

Table 8. Rebuilding exploitation rates by population compared with exploitation rates projected to occur under the proposed 2004 Puget Sound chinook harvest management plan (FRAM 2004; NMFS 2004).

Management Unit	Population	Exploitation Rate		Difference (2004-RER)
		RER	Projected 2004 (So.US)	
Nooksack spring	N.F./S.F. Nooksack	12%	27% (6%)	+15
Skagit spring	Upper Sauk Suiattle	38% 41%	33% (17%) 33% (17%)	-5 -8
Skagit summer/fall	Upper Skagit summer Lower Skagit fall Lower Skagit fall	60% 49% 51%	38% (7%) 38% (7%) 38% (7%)	-22 -11 -13
Stillaguamish summer/fall	North Fork summer South Fork fall	32% 24%	23% (9%) 23% (9%)	-9 -1
Snohomish summer/fall	Skykomish River Snoqualmie River	18% -	29% (13%) 29% (13%)	+11
Green River	Green River	53%	62% (37%)	+9

Table 9. Projected 2004 escapements for Puget Sound Chinook populations compared with recent average escapements and escapement objectives (FRAM 2004; personal communication with K. Rawson, Tulalip Tribe, April 13, 2004). Escapements expected to be above their viable thresholds are noted in bold type.

Management Unit	Population	Escapement: Expected 2004	Escapement: 1999-2002 average	Escapement thresholds: Critical	Escapement thresholds: Viable	Escapement thresholds: Co-manager Goal
Nooksack Early		**570**	429	400	500	
Skagit Spring		1,183	1,075			
	Suiattle	**433**	380	170	400	
	Upper Sauk	**406**	364	130	330	
	Upper Cascade	344	330	170		
Skagit Summer/Fall		19,929	13,810			
	Upper Skagit	**16,182**	10,144	967	7,454	
	Lower Skagit	**2,870**	2,944	200	2,182	
	Lower Sauk	**877**	721	251	681	
Stillaguamish		1,891	980			
	N. Fork Stillaguamish	**1,537**	697	300	552	
	S. Fork Stillaguamish	**354**	283	200	300	
Snohomish		9,341	3,936			
	Skykomish	**4,351**	2,118	1,650	3,500	
	Snoqualmie	4,990	1,818	400		
Duwamish-Green	**Duwamish-Green**	**5,898**	9,299	835	5,523	5,800
Lake Washington	**Cedar River**	414	385	200	1,250	
White River	**White River**	**1,705**	1,220	200	1,000	
Puyallup	**Puyallup**	**2,149**	1,672	200	1,200	
Nisqually	**Nisqually**	**2,079**	1,318	200	1,100	1,100
Mid-Hood Canal	**Mid-Canal Rivers**	298	404	200	1,250	
Skokomish	**Skokomish**	**1,262**	1,503	200	1,250	1,200
Dungeness	**Dungeness**	461	345	200	925	
Elwha	**Elwha**	2,310	2,009	200	2,900	

Puget Sound Chinook ESU Jeopardy Determination

Although populations are essential components of the structure and diversity of the ESU, it is the ESU, not any individual population, which is the listed entity under the ESA. The Puget Sound Technical Recovery Team is charged with identifying the biological characteristics of a recovered ESU as part of developing delisting criteria. These biological characteristics are based on the collective viability of the individual populations, their characteristics, and their distributions throughout the ESU. Using these ESU-wide population characteristics, NOAA Fisheries assesses whether the proposed fishery actions meet its mandates under the Endangered Species Act, the Magnuson-Stevens Fishery Conservation and Management Act, and federal trust responsibilities to treaty Indian tribes.

NOAA Fisheries recognizes that there are various scenarios that may lead to a recovered ESU. Different scenarios may be based on choosing different degrees of acceptable risk of extinction for different combinations of populations across the ESU. However, an ESU-wide scenario with all populations at the lower end of the planning range for viability is unlikely to assure persistence and delisting of the ESU (PSTRT 2002). Therefore, when determining that a proposed harvest action poses no jeopardy to an ESU, a no-jeopardy scenario will likely include populations with a range of risk levels, but when considered in the aggregate, the collective risk will be sufficiently low to assure persistence of the ESU.

The geographical distribution of viable populations across the Puget Sound Chinook salmon ESU is important for the ESU's recovery (PSTRT 2002). An ESU with well-distributed viable populations avoids the situation where populations succumb to the same catastrophic risk(s), allows for a greater potential source of diverse populations for recovery in a variety of environments (i.e., greater options for recovery), and will increase the likelihood of the ESU's survival in response to rapid environmental changes, such as a major earthquake. Geographically diverse populations in different regions also distribute the ecological and ecosystem services provided by salmon across the ESU.

The PSTRT identified five geographic regions within the Puget Sound Chinook salmon ESU and recommended that an ESU-wide recovery scenario should include at least two to four viable Chinook salmon populations in each of the regions, depending on the historical biological characteristics and acceptable risk levels for populations within each region (PSTRT 2002). An ESU-wide recovery scenario should also include within each of these geographic regions one or more viable populations from each major genetic and life history group historically present within that geographic region (PSTRT 2002). While changes in harvest alone cannot recover the Puget Sound chinook salmon ESU, NOAA Fisheries can use the preliminary PSTRT guidance to assist it in evaluating whether the proposed action, in combination with fishing mortality in other fisheries, would impede recovery of the ESU.

The jeopardy determination for the proposed 2004 Puget Sound salmon fishing plan was based on consideration of the proposed management actions taken to reduce the catch of listed fish, the trend in abundance since the Puget Sound Chinook ESU was listed, the status of populations relative to critical and viable escapement thresholds, the magnitude of the remaining harvest, particularly in comparison to the period of decline, and in some cases estimates of target exploitation rates which were derived to be consistent with survival and recovery, i.e., RERs. Consistent with the PSTRT guidance, NOAA Fisheries paid particular attention to the population structure within each region of the ESU by reviewing both the status and impacts on components that were considered representative or important to each region and the ESU as a whole. The jeopardy determination was based on quantitative assessments where possible and more qualitative considerations where necessary. Different methods and different types of information have been used for the various populations within the Puget Sound Chinook Salmon ESU, reflecting what was available or could be developed as part of the 2004 consultation. NOAA Fisheries expects that more quantitative and holistic analyses and risk assessments will become available in time, and that standards may change as new information becomes available. In the meantime, NOAA Fisheries must rely on the best available information in making its judgement about the risk of the proposed action to the listed species.

The Puget Sound Chinook Salmon ESU includes 22 Chinook populations distributed over five distinct geographic areas and several life history types. Puget Sound chinook salmon escapements have been stable or increasing since the ESU was listed in 1999 for all populations in all regions and life history types, an apparent positive response to the decline in exploitation rates in combination with other factors. At the time of the determination, recent years' average escapement for all but the North Fork Nooksack population was above the critical escapement thresholds and two or more of the populations in two of the five regions (10 populations over all regions) exceeded the viable escapement thresholds, representing the range of life history types in each region.

The proposed 2004 Puget Sound fishing plan's management objectives (recovery exploitation rate ceilings, interim escapement goals, critical abundance thresholds, and the minimum fishery regime exploitation rates) for Category 1 and 2 populations captured the full range of genetic diversity and life history traits exhibited by chinook salmon populations identified by the Puget Sound TRT for the ESU. The 2004 fishing plan included management objectives for all Category 1 and Category 2 populations, which were based on either natural-origin production or natural spawning objectives. Where commingled hatchery-origin stocks predominate, co-managers proposed managing fisheries based on the need of the weakest natural population.

Under the harvest regime proposed in 2004, all but one of the populations (North Fork Nooksack) in the ESU was expected to exceed its critical escapement threshold, and 14 of the 19 populations, representing 60% or more of the populations in three of the five ESU regions, were expected to be met or exceed their viable escapement thresholds (assuming current environmental conditions). Although concerns remained regarding low abundance of two of the populations in the remaining two regions, analysis indicated conduct of the 2004 Puget Sound salmon fisheries would have little to no effect on the ability to achieve viability criteria in these regions. Seven of the ten RERs were expected to be met under the harvest regime proposed in 2004. Escapements for the three populations for which RERs were not expected to be met were expected to meet or exceed their viable escapement thresholds in 2004. In combination, this information suggested that conduct of the 2004 Puget Sound salmon fisheries would have little to no effect on the ability to achieve viability criteria for at least two to four populations in each major Puget Sound geographic region, representing the range of life history types within that region (Table 10).

NOAA Fisheries determined that the proposed harvest regime proposed in 2004 1) adequately protected the geographic distribution and life history diversity of natural populations within the Puget Sound ESU; 2) took into account the different risks facing a population depending on the status of the population; 3) addressed harvest as a factor of decline; and 4) provided these protections to the ESUwhile also providing for the exercise of tribal treaty rights and the least disruption to the co-management process between the state of Washington and the Puget Sound Treaty Tribes. Therefore, NOAA Fisheries concluded that the proposed Puget Sound salmon fisheries in 2004 were not likely to jeopardize the continued existence of the Puget Sound Chinook Salmon ESU.

Table 10. Summary of 2004 expectations by major geographic region, watershed category, and life history type in the Puget Sound Chinook Salmon ESU

Geographic Region	Number of Populations	Major Life History	Watershed Category	Stable or above ave. pre-listing escapement[1]	Number of RERs met	Escapement Thresholds Exceeded	
						Critical	Viable
Strait of Georgia	2	spring	1	2/2	0/1	1/2	1/1[2]
Whidbey/ Main Basin	3	spring	1	3/3	2/2	3/3	2/2
	5	fall summer	1 1	3/3 2/2	3/3 2/2	3/3 2/2	3/3 2/2
	2	summer/fall	1	1/1	0/1	2/2	1/1
Southern Basin	5	fall	1/2	3/5	0/1	5/5	3/5
	1	spring	1	1/1	NA	1/1	1/1
Hood Canal	2	summer/fall	2	2/2	NA	2/2	1/2
Strait of Juan de Fuca	1	fall	2	1/1	NA	1/1	0/1
	1	spring	1	1/1	NA	1/1	0/1

[1] The status of a population was considered increasing if the 2000 and 2001 escapements were both above the recent five-year average. Population status was considered declining if the 2000 and 2001 escapements were both below the recent five-year average. Population status was considered stable if one of the 2000 or 2001 escapement was above the recent five-year average and one of the 2000 or 2001 escapement was below the recent five-year average.
[2] Exceeds viable escapement threshold for the management unit.

Summary

The Puget Sound Chinook ESU is one of the most complex ESUs of Pacific salmon. The status of the 22 Puget Sound chinook populations ranges from healthy to critical depending largely on the status of the habitat. Overall abundance of chinook salmon in this ESU has declined substantially from historical levels, and several populations are small enough that genetic and demographic risks are likely to be relatively high. At the time of its original status review prior to listing, NOAA Fisheries listed habitat degradation, the extensive influence of hatcheries, and excessive harvest as factors of decline (Myers *et al*., 1998). All watersheds in Puget Sound have degraded habitat from a variety of causes such as logging, road building, agriculture, urbanization, flood control and hydropower. The degree to which each of these contributes to the decline in habitat quality or quantity varies from watershed to watershed.

The use of hatcheries in Puget Sound is extensive. Much of the hatchery production is for fishery augmentation, but hatcheries are increasingly important for conserving natural populations in areas where the habitat can no longer support natural production or where the numbers of returning adults are so low that intervention is required to reduce the immediate risk of extinction. Significant contributions of hatchery-reared chinook to some systems, South Puget Sound in particular, mask trends in natural production. In response to the ESA listings and regional hatchery reform initiatives, hatchery programs and the associated fishery plans have changed to minimize adverse effects to wild salmon. For populations with a significant hatchery component, fisheries are now managed to provide primary protection to the naturally spawning chinook while shaping fisheries to maximize access to surplus hatchery production. The majority of Puget Sound chinook are now mass marked to assess the contribution of hatchery-origin adults on the spawning grounds, improve broodstock management, and allow for selective harvest opportunity where appropriate.

Significant progress has been made in reducing harvest as a factor of decline. Total exploitation rates have decreased 14 to 63 percent from rates in the 1980 for populations within the Puget Sound ESU. Exploitation rates on Category 1 populations, specifically have been reduced 40-56%. All the Category 1 populations have harvest objectives based on the natural production of the population, and the majority of Category 2 populations are managed for spawning ground escapement objectives rather than solely hatchery program objectives as was past practice. These changes, in combination with possibly improving ocean conditions, have benefitted escapements as evidenced by increased escapements in recent years. Improvements in harvest management and associated hatchery practices affecting Category 2 populations are consistent with the objective to re-establish naturally-sustainable populations in these areas, thereby preserving recovery planning options in these regions.

Puget Sound chinook salmon escapements have been stable or increasing since the ESU was listed in 1999 for all populations in all regions and life history types, an apparent positive response to the decline in exploitation rates in combination with other factors. At the time of the determination, recent years' average escapement for all but the North Fork Nooksack population was above the critical escapement thresholds and two or more of the populations in two of the five regions (10 populations over all regions) exceeded the viable escapement thresholds, representing the range of life history types in each region. The assessment of the proposed 2004 Puget Sound salmon fishing plan suggested that its implementation would contribute to the continuation of these trends and the rebuilding of the Puget Sound Chinook ESU. Monitoring and evaluation programs associated with conduct of the Puget Sound salmon fisheries will be used to continue tracking the status of listed Puget Sound chinook populations and revising harvest objectives as appropriate.

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