AN ABSTRACT OF THE THESIS OF

Ian I. Courter for the degree of Master of Science in Fisheries Science presented on June 8, 2005.

Title: Salmon Recovery in the Pacific Northwest: Defining What Constitutes a Wild Salmon

Abstract Approved:

Redacted for privacy

Robert T. Lackey

In spite of considerable efforts to restore natural runs of anadromous salmonids in the Pacific Northwest, they remain at risk of extirpation. Along with many other factors influencing the decline, stocking from hatcheries over the past hundred years is often suggested to be a major cause. The listing of over two dozen runs of salmon under the Endangered Species Act has catalyzed a re-assessment of hatchery effects on naturally spawning salmon. Recent policies have placed a much greater emphasis on restoring runs of wild salmon rather than maintaining runs through stocking from hatchery production. Except at the most superficial level, there is no consensus about how to define "wild." Rather, there is a continuum of definitions for "wild" and each definition supports an implicit policy goal. The precise way in which "wild salmon" is defined potentially has profound policy implications.

Ultimately, the choice of definition is a policy decision that incorporates science as one of several factors influencing the decision. A suite of options, often poorly articulated, for defining "wild" are available to policy makers who are selecting recovery goals. To test a subset of the available definitions of wild, I quantified the number of hatchery and naturally spawning salmon for 19 populations of Oregon coastal coho. "Wild" was defined by types 1 through 5 based on the number of hatchery fish released annually and the number of naturally spawning hatchery adults. As currently managed by the Oregon Department of Fish and Wildlife, the Oregon coast has a range of "types" of coho salmon. By clearly and explicitly defining "wild" as steps along a continuum, policy makers and managers can more effectively monitor and achieve specific salmon recovery goals.

# Salmon Recovery in the Pacific Northwest: Defining What Constitutes a Wild Salmon

by

Ian I. Courter

A THESIS

submitted to

Oregon State University

In partial fulfillment of
the requirements for the
degree of

Master of Science

Presented June 8, 2005
Commencement June 2006

Master of Science thesis of Ian I. Courter presented on June 8, 2005.

APPROVED:

Redacted for privacy

Major Professor, representing Fisheries Science

Redacted for privacy

Head of the Department of Fisheries and Wildlife

Redacted for privacy

Dean of the Graduate School

I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

Redacted for privacy

Ian I. Courter, Author

# ACKNOWLEDGEMENTS

It would be impossible for me to adequately thank those that played an important role in equipping me to write this thesis, nor could I mention the names of all those that contributed to my education and passion for natural resource policy. That said, I would like to thank my wife Lauren without whom I would not have survived graduate school or any other endeavor for that matter. Secondly, I would like to acknowledge and thank Dr. Robert T. Lackey for taking me under his wing and being the kind of mentor that inspires students to excel. Dr. Lackey made my graduate school experience a joy. Lastly, my father who inspired me to be great at everything I do and shared his love of nature with me.

## TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

# LIST OF FIGURES

Salmon Recovery in the Pacific Northwest: Defining What Constitutes a Wild Salmon


**Abstract**

In spite of considerable efforts to restore natural runs of anadromous salmonids in the Pacific Northwest, they remain at risk of extirpation. Along with many other factors influencing the decline, stocking from hatcheries over the past hundred years is often suggested to be a major cause. The listing of over two dozen runs of salmon under the Endangered Species Act has catalyzed a re-assessment of hatchery effects on naturally spawning salmon. Recent policies have placed a much greater emphasis on restoring runs of wild salmon rather than maintaining runs through stocking from hatchery production. Except at the most superficial level, there is no consensus about how to define "wild." Rather, there is a continuum of definitions for "wild" and each definition supports an implicit policy goal. The precise way in which "wild salmon" is defined potentially has profound policy implications. Ultimately, the choice of definition is a policy decision that incorporates science as one of several factors influencing the decision. A suite of options, often poorly articulated, for defining "wild" are available to policy makers who are selecting recovery goals. To test a subset of the available definitions of wild, I quantified the number of hatchery and

naturally spawning salmon for 19 populations of Oregon coastal coho. "Wild" was defined by types 1 through 5 based on the number of hatchery fish released annually and the number of naturally spawning hatchery adults. As currently managed by the Oregon Department of Fish and Wildlife, the Oregon coast has a range of "types" of coho salmon. By clearly and explicitly defining "wild" as steps along a continuum, policy makers and managers can more effectively monitor and achieve specific salmon recovery goals.

## Section1: Overview of the Wild Salmon Debate

### 1.1 Introduction

Salmon populations in California, Oregon, Washington, Idaho, and southern British Columbia are much reduced as compared to pre-1850 levels (Meengs and Lackey 2005). As of 2005, twenty-six distinct population segments of Pacific salmon and sea-run trout have been identified as endangered or threatened under the U.S. Endangered Species Act (ESA)(1973). Proposals to list additional population segments await review. As mandated and defined by the ESA, any "species" determined to be at risk must be protected and preserved by the actions of all federal agencies {ESA§2(c)(1)}. Further, individual state laws require Oregon, Washington, Idaho, and California to conserve, protect and restore their state listed salmon populations. In addition, the Canadian Species At Risk Act (SARA) (Irvine 2005), may result in the listing of several salmon populations in British Columbia as "at risk."

The policy and science debate about how to identify "at-risk" salmon has been confounded by extensive releases of young salmon from hatcheries for more than 125 years (Wahle and Smith 1979; Wahle and Pearson 1987). During

Pacific Northwest peak cannery operations (1870s through the early 1900s) along the lower Columbia River and the Oregon coast, salmon populations were rapidly declining. Natural production was insufficient to sustain harvest levels. Unwilling or unable to reduce harvest rates, managers considered solutions that would sustain the harvest levels indefinitely. One potential and obvious answer was artificial propagation (Wilkinson 1992).

Salmon runs (both naturally produced and those supported by hatchery releases) in the Pacific Northwest are much reduced from their historical levels. Meengs and Lackey (2005) estimate that coho salmon (*Oncorhynchus kisutch*) runs on the Oregon coast are 5 to 20% of historical levels (prior to the 1850s), including hatchery fish. Faced with low salmon runs, policy makers have continued to use supplemental stocking to maintain fishable populations of salmon.

Commercial, sport, and tribal salmon fishing in California, Oregon, Washington, and Idaho is still largely dependant on artificial propagation. The indirect or secondary economic benefits of sport or commercial fishing are considerable and there continues to be strong public pressure to continue stock augmentation. The development of the ESA, SARA, and other environmental statutes has, however, forced policy makers to reevaluate augmentation, conservation stocking programs, and any type of artificial propagation to sustain or enhance runs of salmon.

In addition to support from fishing interests, there is also advocacy from other groups to restore salmon runs. To some people, salmon are an icon species of the region, and a surrogate for the quality of life in the Pacific Northwest. In spite of millions of dollars being invested every year on efforts to restore salmon, salmon populations continue to decline (Huntington 1996; Lichatowich 1999) and recovery appears problematic over the long term (Lackey 2003).

Unlike any other ESA listed species, free-living salmon are regularly and legally harvested at relatively high levels. Salmon in the retail market are also widely available year round and are relatively inexpensive, in large part due to aquaculture production in Chile, Scotland, Norway, and Canada. Hatcheries have also been used extensively to supplement dwindling natural runs. For some interest groups, hatchery and aquaculture production is sufficient to satisfy their policy concerns and possibly ESA mandates. For other groups, restoration means returning naturally spawning salmon populations to self-sustaining levels that are sufficient to permit intense fishing. Regardless of personal policy preferences, the ESA is remarkably ambiguous about defining "recovery" and leaves considerable room for the discretion of the government agency designated to implement the ESA (NOAA Fisheries in the case of anadromous salmon) or to be interpreted by the courts.

For the past 150 years, and especially since the 1991 listing of the first group of "at risk" salmon, the policy debate over salmon recovery has been befuddled with various definitions of wild and hatchery salmon. The policy choices are often not clearly articulated, in part because the options are not simple dichotomies and, in part, because some of the words used are confusing and/or misleading.

Perhaps the most confusing term used in the public dialog surrounding salmon policy is the term "wild." "Wild" carries many varying connotations, and whether a specific connotation is adopted is a reflection of an implied policy preference. The roots of this conflict are grounded in the fact that biologists, policy makers, and lay citizens are rarely talking about the same thing when they say "wild." Worse, policy analysts and decision-makers often do not recognize this. Many biologists and policy makers, when told that "wild" has many meanings, will acknowledge this fact and proceed to discuss the issue by defining "wild" within the context of their own policy preferences.

When variably defined and value-laden terms are used for both science and policy concepts, the result is often similar to the current wild salmon debate—lobbyists couch the policy argument in "science" terms, policy makers avoid the difficult value choice because they see it as a "science" issue, and the public becomes confused by the lack of clear policy choices.

### 1.2 Why Augmentation and Conservation Stocking Has Become Controversial

The widespread, long-term use of stocking from hatcheries to increase salmon runs in the Pacific Northwest has brought up many concerns about the effects of artificially propagated fish on naturally spawning salmon stocks (NRC 1996). Although hatchery operations have evolved substantially since the late 1800s, genetic and behavioral differences between natural and hatchery salmon raise a fundamental policy question: is stocking from salmon hatcheries helping or hurting naturally spawned salmon stocks? Similarly, can stocking from hatcheries be used successfully to rebuild naturally spawning populations?

Through simulating optimal environmental conditions and minimizing human and non-human causes of mortality, some contemporary hatchery programs attempt to minimize potential impacts of artificially propagated salmon on naturally spawned fish and their habitats (ODFW 2003).

Opinions differ dramatically on whether hatcheries should continue to be an important tool for salmon recovery efforts. The Native Fish Society (NFS) for example, advocates for the conservation, protection, and restoration of native fishes in the Pacific Northwest, and its members are vehemently opposed to the use of hatcheries to restore depleted runs of salmon. One of NFS's top five policy objectives is to "prevent interbreeding and ecological interactions between hatchery and wild fish (NFS 2002)." Contrarily, the Pacific Fisheries Management Council (PFMC) argued that hatcheries (PFMC 2003):

> *...are widely supported institutions that have been intended to supplement natural production of salmon, replace production where wild stocks have declined, and serve as an educational tool to increase public awareness of fish and their significance.*

Of particular importance in the hatchery debate is whether or not strays (artificially propagated salmon that do not return to their hatchery of origin and spawn with the natural population in natural habitat) alter the genetic characteristics of naturally spawning populations, and whether such alterations have any ecological or policy significance.

Some scientists hypothesize that hatchery-bred salmon that spawn naturally with non-hatchery-bred fish cause an overall reduction in fitness (defined as the ability of a salmon to produce offspring that survive and reproduce) of native populations. Goodman (1990) writes that:

> *...the declining productivity of both hatchery and wild populations is attributable, at least in part, to destruction of adaptive gene pools that has occurred already through processes other than the overfishing and habitat loss envisioned by Congress when it designed the ESA's listing mechanism.*

Others, however, believe that processes of natural selection could prevent hatchery genes from permanently affecting the population (Fleming 2004). Nickelson (2003) found that hatchery strays in 14 populations of coho from the

Columbia River to Cape Blanco, Oregon, did not affect the overall productivity of the natural coho populations.

Although the long-term effect of hatchery strays on naturally spawning populations remains uncertain, evidence of breeding between naturally spawned salmon and hatchery strays is not. The Oregon Department of Fish and Wildlife estimated that hatchery strays represented 33% of the spawning population of coho on the Oregon Coast in 1990. Since 1990, this percentage steadily declined and reached 1.8% by 2004 (ODFW 2005a).

In addition to potential problems caused by interbreeding, some believe that other drawbacks commonly arise because of the influx of millions of hatchery fish each year including, increased predation due to high concentrations of fish, excessive competition for food, the spread of disease from the hatcheries to the naturally spawning population, and mixed (hatchery/naturally spawning) stock fishing that removes the less abundant (and perhaps ESA listed) naturally spawned salmon along with the abundant hatchery produced salmon.

Although stocking has vocal critiques, such programs maintain public support because of their ability to maintain large salmon runs that support commercial, sport, and tribal fishing. Without augmentation of salmon populations with artificially propagated fish, fishing opportunities for salmon would decrease substantially.

**1.3 Biological Differences between Hatchery and Naturally Spawned Salmon**

There are many assertions about the differences between hatchery and naturally spawned salmon. To some individuals active in salmon management, it is an article of faith that hatchery fish are less "fit" (referring to their ability to survive and reproduce) than "wild" fish. In spite of such claims, it is difficult to find compelling evidence to support or refute this assertion. Most often, biological reviews of the issue theorize that hatchery salmon must be less fit because they were spawned in captivity. However, other studies report that the fecundity of adult hatchery salmon is equal to that of naturally spawned adult salmon, indicating that hatchery salmon fitness may not be different at least with respect to reproductive ability (Lannan 2002; Nickelson 2003). The only uncontested difference between hatchery and naturally spawned salmon is that hatchery salmon are artificially spawned in a hatchery while naturally spawning salmon reproduce without direct human intervention.

Problems caused by specific but potentially undesired management practices versus those problems caused by artificial propagation in general are often confused (Brannon et al. 2004). Asynchronous spawning timing is a good example of such confusion. Hatchery fish returning to spawn earlier than the natural population is usually the result of a choice made by hatchery managers to select early returning fish as their brood stock. Over time, as is the case for Washougal River (Washington) hatchery fish, early selection of brood stock can change spawning timing by as much as three months (Brannon et al. 2004). Early selection was a choice based on the salmon management policies in place at that time. Managers could have selected brood stock to maintain synchronous run timing with the naturally spawning population. Such examples are often cited as evidence that poor adaptability and genetic inferiority of hatchery fish is the source of the early spawning problems. Brannon et al. (2004) characterized his argument this way:

*There is general agreement that the indiscriminant use of hatchery fish has contributed to the decline of native fish in the Pacific Northwest, but there is no* *evidence that such decreases were the result of artificial propagation. For that reason it is important to differentiate between the effect of management decisions involving the use of cultured fish, and the effect of artificially propagated fish on the corresponding natural population.*

Lab studies to compare the fitness of wild and hatchery salmon have proven inconclusive because results are difficult to relate to natural populations where so many other confounding factors affect salmon survival and reproduction. In addition, field studies have often used non-native hatchery stocks when comparing hatchery and naturally spawning fish (Reisenbichler et al. 2004). In some instances, both laboratory and field studies have shown conflicting results concerning the differences between hatchery and naturally spawning salmon fitness (Brannon et al. 2004).

### 1.4 Confusion Caused by Mixing "Science and "Values"

Why do so many fisheries biologists appear to argue that hatchery fish are less fit? Either they have a strong belief in the accuracy of their theories in spite of limited direct or published evidence to support them, and/or they have a strong personal policy preference against using supplemental stocking for restoring salmon runs. Where does the fervor to support or oppose hatchery operations arise? The answer seems to revolve around personal values and the resulting implicit policy preference. Beyond the vigorous debate among scientists over difficult science questions, only personal values and policy preferences separate the hatchery proponents from hatchery opponents. The values of hatchery advocates and antagonists are not based on definitive scientific evidence, nor can they be. They are simply preferred policy positions.

To illustrate how powerful personal values are in the salmon debate, consider a hypothetical scenario where hatchery operations are strictly policed. Further, assume that through artificial propagation of salmon, managers could produce salmon that were identical in every way to naturally spawned salmon. Furthermore, assume that salmon runs could be sustained in perpetuity using artificial propagation. Would there still be opposition to the use of hatcheries to supplement runs? Some biologists and certainly many policy advocates probably would still oppose the use of supplemental stocking for restoring of salmon. Conversely, if biologists were able to prove convincingly that hatchery operations alter the natural stocks, it is likely there still would be many who support supplemental stocking to maintain large, fishable runs because hatchery fish can be produced in vast numbers even though salmon might individually have a lower survival rate. Simply put, the primary driving force behind this debate is not science, it is values.

### 1.5 Various Meanings of the Term "Wild"

Using a value-laden term like "wild" to describe a controversial concept leads to more policy controversy and ambiguity. It is important to consider the societal context when choosing a term to describe an ecological condition or state. In the early 1800s, the term "wild" carried a negative connotation. Wild was used to describe things that were unknown, dangerous, or that needed to be controlled or conquered. By the 1960s, evolving societal priorities (at least in North America) transformed "wild" into a word with more positive connotations such as pristine, untouched, beautiful, and desirable. Earlier connotations however, had not been lost entirely. "Wild" has since evolved into a complex term whose connotation depends on the worldview of the user and the listener. Thus, wild is a policy term; not a scientific one.

The term "wild salmon," has an implicit context and definition. To define the context of "wild" and "hatchery" salmon, the values being used must be specified. "Wild" may carry either a negative or a positive connotation depending on a person's values and beliefs.

Of the many practical salmon policy questions faced by policy makers and the public generally, the answer to the question, "what is a wild salmon," is critical to the restoration and sustainability of salmon in the Pacific Northwest. It is imperative to be clear about the way "wild" is defined. In policy and science dialog, the term "wild" is rarely precisely defined. It is usually used to describe any organism that is not held in captivity, but the degree of human influence on the organism in question may vary. For example: was the organism in question previously held in captivity, or perhaps it was artificially propagated? Opinions quickly diverge and the debate about what is "wild" emerges.

### 1.6 Role of Science in Resolving Salmon Policy

Unbiased, either in reality or perception, comparative analysis of biological information about naturally-spawned and hatchery-spawned salmon is sparse. However, a wealth of anti- and pro-hatchery salmon literature flood the media and even peer reviewed scientific publications. It is also not uncommon for scientific reports and assessments to implicitly support particular definitions of "wild" for policy purposes. This type of literature is not flawed because it promotes a policy view, but when touted as unbiased or "science based," it undermines the legitimate role of science in policy deliberations (Lackey 2004a). Normative science (defined as "science" that conveys an implied policy preference) is not always practiced intentionally in the wild salmon debate, but it continues to be misleading to the general public and often frustrating to policy makers (Lackey 2004a). Normative science is perhaps the most subtle form of ecological policy advocacy because users typically assume that "science based" information is policy neutral.

There are many examples of policy advocacy masquerading as scientific information. For example, Myers et al. (2004) explained the scientific basis of the controversy about whether hatchery fish should be counted as part of Evolutionarily Significant Units (ESUs). The authors presented a fairly one-sided consideration of the available scientific information about hatchery salmon fitness, and conclude:

*Hatcheries generally reduce current fitness and inhibit future adaptation of natural populations. Hence, the legal definition of an ESU must be unambiguous and must reinforce what is known biologically (Myers et al. 2004).*

The scientific basis for this statement is debatable, yet to the unsuspecting reader who knows little about hatchery and wild salmon, their suggestion not to include hatchery fish as part of ESUs appears to be scientifically undisputed. To suggest not considering hatchery salmon as part of an ESU is a statement of the authors' policy preference. Even if the science concerning the relationship between hatchery and "wild" salmon was undisputed, it would not necessarily lead to adopting any particular policy option.

Other types of policy advocacy masquerading as science are less ambiguous. Interest groups and policy advocates are often straightforward with their beliefs about the role, if any, of hatchery augmentation and supplementation. However, interest groups often present only one side of the relevant scientific information. This dichotomy between interest groups (policy advocates) has created a proverbial "dueling science" policy dialog with each side attempting to overwhelm policy makers with one-sided scientific information.

## Section 2: What is Wild: a confluence of science, values, and policy preferences

The debate over "what is wild" does not swing on the balance of genetics or ecology, but on societal preferences. In the abstract, the goal for salmon recovery is, of course, dictated by the whole of society rather than the more vocal, energetic, or powerful advocates. Science's role in establishing this goal is to state the relevant facts and assess, in part, the viability of each policy goal (Lackey 2004b) so that recovery strategies will better meet and more quickly achieve society's goals for salmon in the Pacific Northwest. In the abstract, everyone would like to see salmon thrive through the next century, but at what cost? Those interested in the conservation of natural salmon populations may place a high value on their survival and therefore be willing to accept a relatively large change to lifestyles for the benefit of salmon populations. Others may not consider salmon a high priority when aligned with competing demands on public resources such as school, health care, national defense, roads, etc? The crux of developing policy is that policy makers must consider more than science or single policy goals. Salmon policy making involves balancing competing priorities that reflect society's values and goals within what is ecologically possible.

Although the extent of the differences between hatchery and naturally spawned salmon continues to be debated among scientists, until goals for salmon recovery are specified and agreed upon by the larger public, the outcome of this science debate is not terribly important from a policy standpoint. Even if a complete body of knowledge and understanding emerged regarding the behavioral and genetic characteristics of the two types of salmon, The same policy question would remain: What is the goal for salmon recovery?

Some participants in the salmon policy debate assume that the results of a scientific study, will somehow lead directly to a specific policy outcome. This type of attitude towards salmon policy causes many advocates to continually search for the "smoking gun"—the study that finally puts an end to the arguments for or against the use of hatcheries, but "wild" is a value judgment and therefore a policy determination, not a scientifically derived term. "Any naturally spawned fish" is often the definition used to describe "wild," but selection of this definition is an implicit policy decision. It is equally valid to argue that an adult hatchery fish making its way upstream to spawn naturally is also wild.

During early hatchery operations, the management goal was straight forward: produce enough salmon to mitigate the loss of habitat and adult spawners in order to maintain salmon runs at high, fishable levels. Concerns about the ecological impacts of hatchery releases resulted in more effort to close hatcheries than reform them. Ultimately, society's goal for recovery will dictate the direction of hatchery reform (Fuss 1998).

As in most policy issues, most of the debate takes place between those who have the most at stake. This may explain why so few efforts have been made to reform hatchery operations. There are those who are apprehensive about changing hatchery practices in ways that reduce run sizes, and those who would like to see hatchery operations stopped altogether. A specific policy goal would define the management prospective and ultimately drive hatchery practices to account for the relevant ecological concerns (Brannon 1993).

## Section 3: The Wild Salmon Continuum Concept

Assuming that maintaining runs of "wild" salmon is the desired public policy objective, advocacy groups (Native Fish Society, Trout Unlimited, Indian tribes, sport fishing interests, etc.) aggressively push to have their definition adopted in policy debates and everyday use. At one extreme, "wild" is purely a question of heredity: was the salmon spawned in the wild from adults who were also spawned naturally? At the other extreme, those whose main concern is the availability of salmon for harvest by sport or commercial fishing may prefer to define "wild" as any free-living salmon. In the later view, a salmon released from a hatchery and living unconfined by cages or pens would be wild. There is not a single definition for wild, but the particular definition used tends to lead to a specific policy prescription (Figure 1).

The way in which "wild salmon" is defined potentially has profound policy implications. When considering the genetic versus free-living definitions above, recovery strategies would change greatly based on the choice of definition and implicit recovery goal. A river used heavily for commercial fishing may be managed by implicitly defining "wild" as free-living. Such management practices would require hatchery supplementation of the naturally produced salmon run so that fish yields could remain high in spite of habitat alteration. On the other hand, managers of a stream running through a national park might opt for a more genetically pristine management strategy since the purpose of the park's establishment may have been to preserve unaltered ecosystems. Any chance of genetic or behavioral effects from hatchery fish might not be acceptable.

When presented with the two extremes of what is "wild," the stark contrast between the ways of thinking is obvious, but differences exist that give rise to a suite of possibilities for defining wild (ODFW 1985; Bayer 1989; Lackey 2004b). The concept of a continuum is a more accurate way to describe the suit of possible definitions.

Of the many potential definitions of wild, five are proposed here that are representative of the range of the continuum. They also tend to be the most often used by policy makers, advocates, and scientists:

1. Any salmon none of whose ancestors had ever been held in captivity.
2. Any salmon spawned naturally and whose parents spawned naturally.
3. Any salmon spawned naturally.

4. Any salmon spawned from locally based gene pools.
5. Any free-living salmon.

Using the fifth definition of "wild," *any free living salmon*, is at one extreme. Under this definition, any salmon, regardless of genetic stock or where and how it was raised, once in the water and unconstrained by human barriers, is wild. Such a definition would include released hatchery and escaped aquaculture fish. All free living salmon would be included in an analysis of population size or recovery strategies.

The fourth definition, *any salmon spawned from locally based genetic pools*, is similar to the first, but has a difference with respect to the source of genetic variation. Most population segments of salmon, although the same species, represent distinctly different genetic pools of variation and have characteristics specific to the habitat of a particular environment. Some would argue that as long as the spawning adults are from the same local population, their free-living offspring are wild. This definition also includes hatchery derived salmon when the brood stock is obtained from the resident population.

The third definition, perhaps the most common way of defining wild, is *any salmon spawned naturally*. This does not include hatchery fish that have recently been released as juveniles, but it does include the offspring of strays that will hatch and rear naturally, the first generation hatchery and wild crossed salmon. The second generation offspring coincides with the second definition on the list (*any salmon spawned naturally and whose parents spawned naturally*).

The first definition, *any salmon none of whose ancestors had ever been held in captivity,* is at the other and most restrictive extreme. In this case, none of the salmon's previous generations have ever been reared in a hatchery. For populations that have been supplemented by hatcheries for over a century, whether or not there are any salmon in California, Oregon, Washington, and Idaho that could be classified this way is problematic.

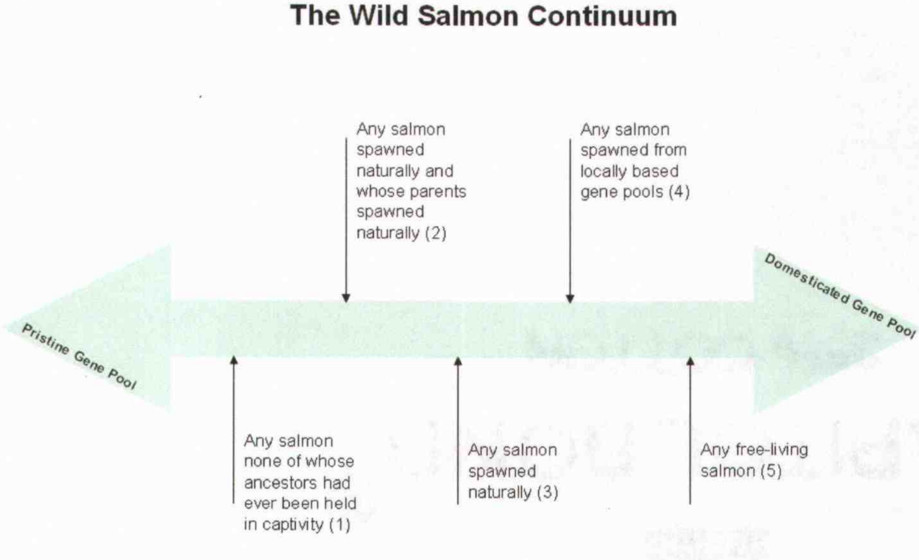
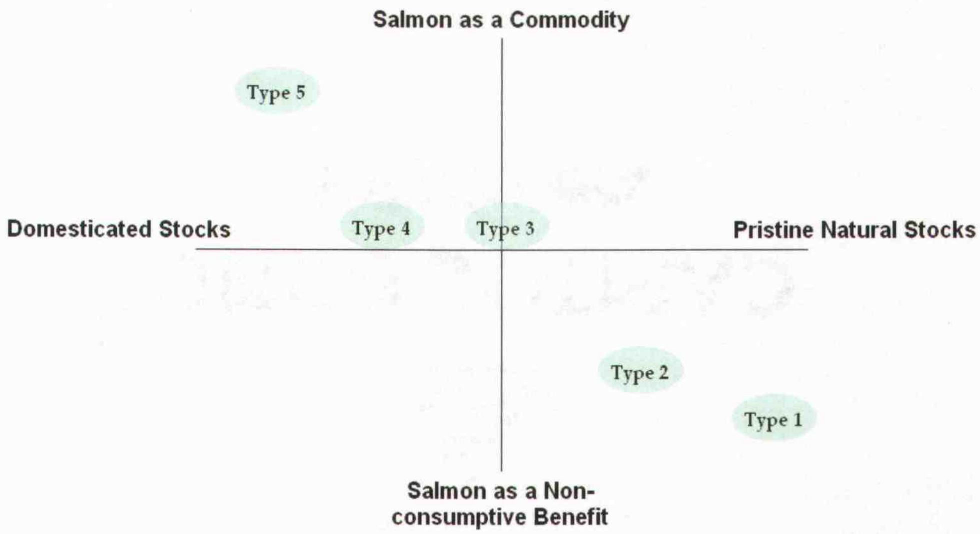



Figure 1: The continuum of definitions of "wild" correlated with the continuum of policy objectives.

## Section 4: Applying the Continuum Concept

### 4.1 An Alternative to Using the Term "Wild"

An option for policy makers who wish to move away from the use of the traditional concept of "wild" is to organize salmon with different lineages into categories (Types 1 through 5). From these clearly defined categories, policy makers could select the types that are appropriate for specific management goals and adjust hatchery practices and regulations accordingly (Figure 2).




**Type 1**: Any salmon none of whose ancestors had ever been held in captivity
**Type 2**: Any salmon spawned naturally and whose parents spawned naturally
**Type 3**: Any salmon spawned naturally
**Type 4**: Any salmon spawned from locally based gene pools
**Type 5**: Any free-living salmon

Figure 2: Wild Types 1 through 5 and their approximate position within the range of potential policy objectives.

By categorizing salmon by types along a continuum, it is no longer necessary to use common words uncommonly and it reduces the confusion caused by using controversial and semantically nuanced terms such as "wild." Although this approach is different than the more traditional tactic of selecting a single definition, the foundational idea is the same—start with a policy goal and then choose the most appropriate defining term. The following case study applies the proposed concept.

**4.2 Case Study**

Salmon recovery along the Oregon coast provides an excellent situation in which to test the continuum concept. A similar approach was taken by the Oregon Department of Fish and Wildlife Coho Salmon Plan Status Report (ODFW, 1985) in which "wild" was categorized by three Types: A, B, and C. Applying the continuum approach proposed here involves assessing the probability that the pre-1850s gene pool was altered as the percent of hatchery salmon in the population increases along the continuum from left to right (Figure 3).

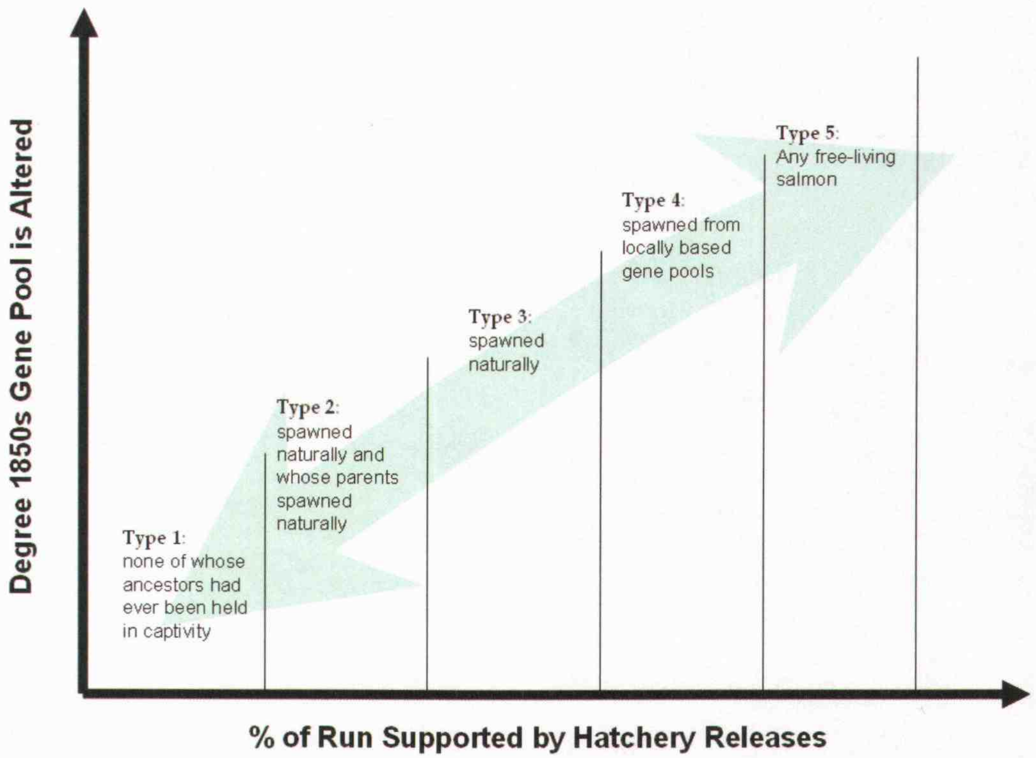



Figure 3: Hypothesized effects of supplementation on pre-1850s gene pools along the "wild" salmon continuum

Particularly in the southern part of their range (California, Oregon, Washington, and British Columbia), artificial coho production is essential for sustaining large, fishable populations, yet hatchery supplementation could present risks to naturally spawning salmon populations (NFHRP 1994; ISG 1996; NRC 1996). Because of these risks, as part of the Oregon Plan for Salmon and Watersheds (CSRI 1997), much of Oregon coastal coho artificial production has been suspended (Lewis 2005). Other factors, such as inadequate funding, also likely played a significant role in the decrease of supplementation programs

(Chilcote 2005). In spite of recent reductions in coho releases from hatcheries, hatcheries continue to play an important augmentation role. Though artificially propagated fish make up just less than 10% of the total number of spawning coastal coho in Oregon, in some populations (e.g. Upper Umpqua and Salmon) the numbers of hatchery coho often exceed 40% of the naturally spawning population annually (Figure 4). ODFW's current coast wide policy is to maintain less than 10% hatchery salmon within the naturally spawning population to minimize potential effects on naturally spawning salmon (ODFW 2005b). Complete suspension of all Oregon coastal coho augmentation and supplementation programs, at least in the near future, is unlikely because of public pressure to maintain fishing opportunities (Smith et al. 1997).

To evaluate the total numbers of naturally spawning coho and the percentage of hatchery strays, data was obtained from ODFW. Estimates of coho spawning abundance were based on stream spawner counts between 1998 and 2003. To account for the impact of marine survival on the numbers of returning spawners, the data were spilt into two categories: good (1998-99) and poor (2000-03) ocean conditions. Annual spawners for good and poor ocean conditions were averaged and the percentage of hatchery spawners was estimated as an average of the number of hatchery coho that were observed on the spawning grounds

(Figure 4). Because of considerable changes in hatchery management around 1994, subsequent reduction in the number of hatchery salmon released annually (ODFW 2005b), and changes in ocean conditions affecting marine survival rates; hatchery percentages are lower than previous similar analyses (Nickelson 2003).

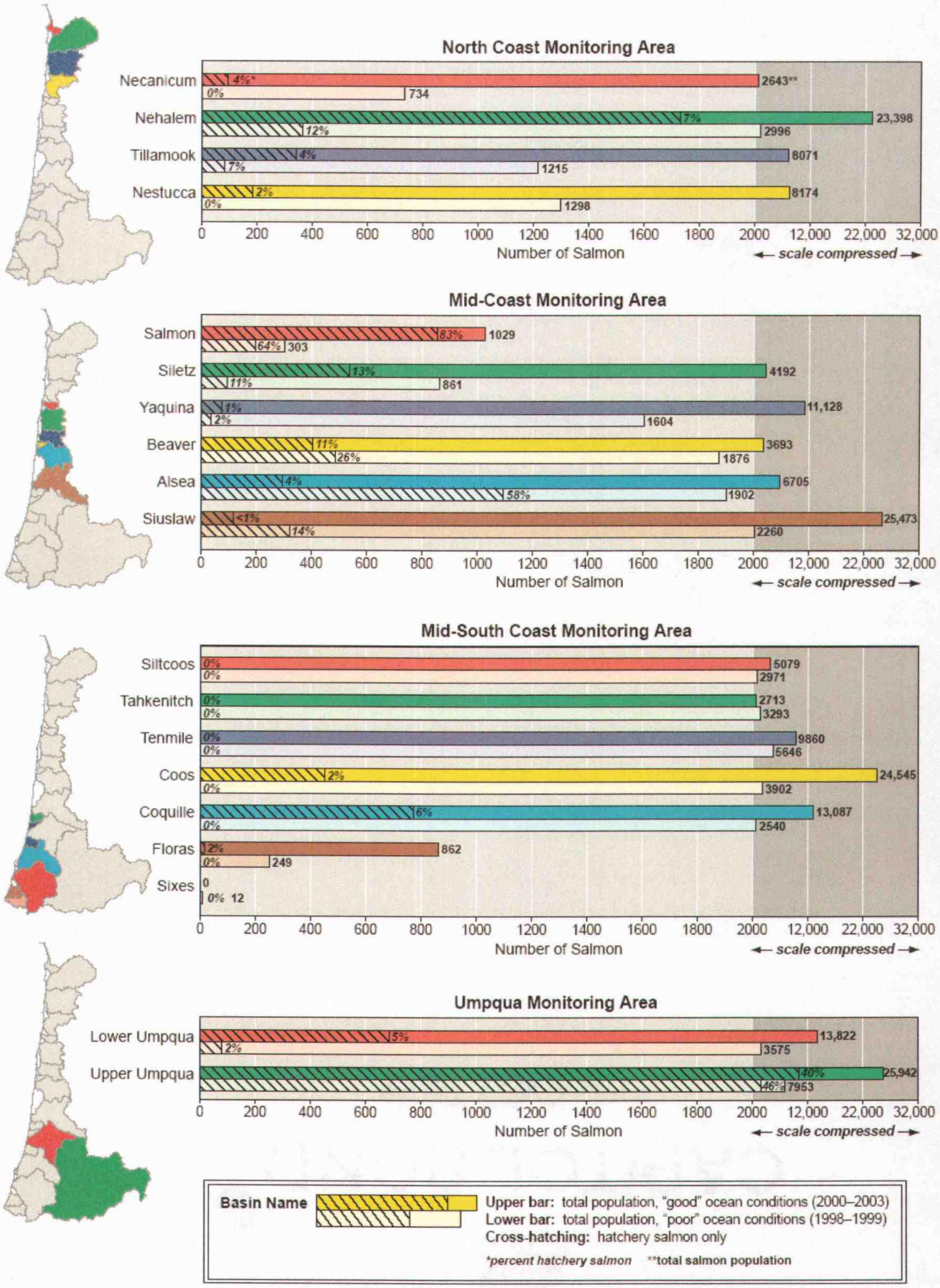



Figure 4: Average number of spawning coho and percentage of hatchery strays by population on the Oregon coast during "good" ocean and "poor" ocean conditions.

Though managed as a metapopulation (ODFW 2005c), the Oregon coho ESU has a variety of different supplementation and augmentation programs across its 19 populations (Figure 5). The percent of hatchery coho in the naturally spawning populations ranges from 0 to over 80% along the coast. Run size is not the only driving force behind augmentation and supplementation. For example, the Siuslaw population has over 25,000 coho spawners and less than 1% of those are hatchery strays, while the Upper Umpqua Basin has approximately the same number of spawners, but hatchery fish make up 40% of the population (Figure 4). Hatchery coho currently have important influence within the Umpqua basin and others with high percentages of hatchery spawners.

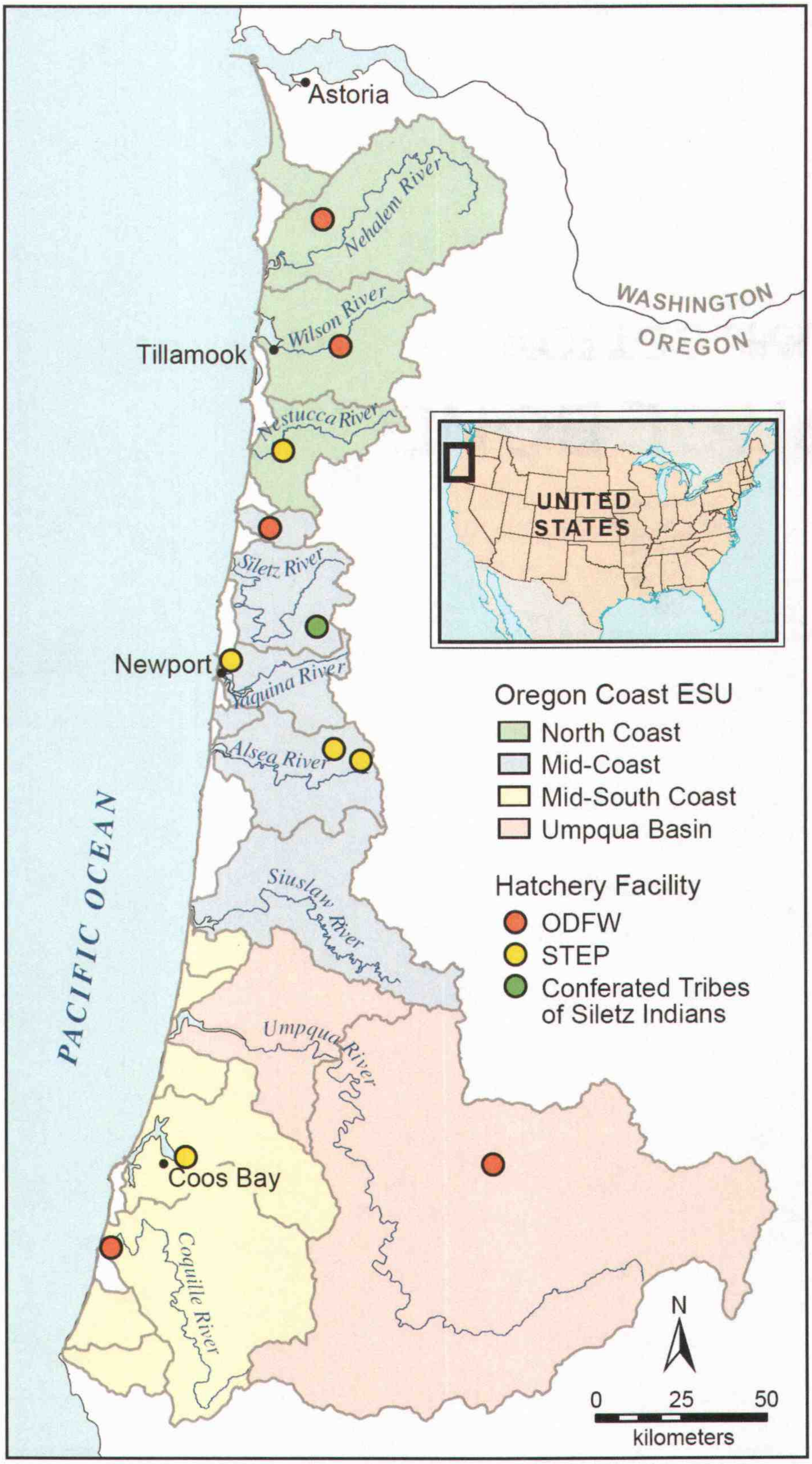



Figure 5: Populations of the coastal coho Evolutionarily Significant Unit as defined by ODFW (2005c) and the approximate locations of active hatchery programs.

The variety of implied policy objectives within coho populations is demonstrated by the geographic distribution and variable production size of hatcheries on the Oregon Coast. Hatchery programs such as the Salmon River, for example, considered an isolated augmentation program, are producing large numbers of coho with the expectation that over 80% of the annual spawning population will consist of hatchery strays, yet augmentation continues with the goal of bolstering coastal fishing. Other hatchery programs such as the Coos and Bandon facilities produce coho for conservation as well as augmentation purposes. Conversely, in some populations there has not been any kind of supplementation or augmentation since 1990.

Specific objectives for each population of Oregon coastal coho have not been explicitly defined and documented by ODFW, but the need for a conservation strategy that addresses coho by population has long been recognized (Chilcote 2005; Lewis 2005). To test the usefulness of the wild salmon continuum concept proposed here, the continuum could be applied to each population based on the current distribution of hatcheries and their relative production amounts historically and currently. The production numbers for hatcheries along the coast do not necessarily reflect the actual management objectives for those populations (objectives have yet to be formalized), but this analysis will serve as an example for how the wild salmon continuum could be used. There are four caveats:

(1) *The decision to assign a definition of "wild" to any particular basin is arbitrary (The purpose of this section is not to argue for or against any particular definition of "wild", but rather to demonstrate how the wild salmon continuum concept could be applied to relevant salmon policy problems).*

(2) *The number of hatchery coho spawning naturally and supplementation releases are used as the main criteria for determining the definition of "wild" for each basin, but there are other economic, political, and social influences that determine hatchery output (For the purposes of this analysis, it is assumed that ODFW is regulating hatchery production based solely on achievement of their objectives for coho salmon).*

(3) *The focus of this analysis was on ODFW hatcheries. Private, tribal, and Salmon-Trout Enhancement Program (STEP) hatcheries were considered, but ultimately carried less weight when deciding how to define wild. [With one exception (Siletz Hatchery), non-ODFW*

*hatcheries produced far fewer fish than ODFW hatcheries and likely contributed relatively small numbers of fish to the naturally spawning populations].*

(4) *The analysis of Oregon coastal coho by population is based on supplementation and augmentation program data from 1990 to 2003 (Supplementation and augmentation prior to 1990 was not considered when designating the type of "wild" coho managed for by ODFW).*

*Type 1: None of whose ancestors have ever been held in captivity*

None of the 19 populations of salmon was given a Type 1 designation (Table 1). Any impacts from straying in populations that do not have active supplementation programs probably have been mitigated over time through natural selection, but it would be difficult to conclusively categorize any of the coastal coho populations as Type 1. The presence of supplementation programs within or adjacent to all 19 populations between 1990 and 2003 (and in prior years) suggests that ODFW did not and does not manage for Type 1 coho.

*Type 2: Spawned naturally and whose parents spawned naturally*

Type 2 was one of the most prevalent designations (Table 1). Six of the populations fall within this definition of "wild" (From North to South: Nestucca, Beaver, Siltcoos, Tahkenitch, Tenmile, and Sixes). Type 2 populations have not been involved in supplementation programs since 1994. Prior to 1994, annual supplementation was typically moderate to low in numbers of releases (1,500-2,000). Siltcoos is the one exception. A small release of 1,500 juveniles was released in 1997. This was the only supplementation within this population since 1990.

*Type 3: Spawned naturally*

There were six Type 3 designations: Necanicum, Yaquina, Alsea, Siuslaw, Lower Umpqua, and Floras (Table 1). While none of these populations has current supplementation programs, all have had significant programs that stopped between 1997 and 2002. Due to the recent and consistent releases in these populations since 1990, it is likely that any effects of hatchery salmon on the naturally spawning population are still present. As time progresses, if there is no supplementation, these populations could eventually evolve into Type 2 designations.

*Type 4: Spawned from locally based gene pools*

Type 4 designations were concentrated in the southern Oregon coastal coho populations: Upper Umpqua, Coos, and Coquille (Table 1). All three populations have active supplementation programs that use local broodstock. Approximately one third to one half of the broodstock is collected from the naturally spawning population to ensure adequate genetic mixing and reduce domestication of the hatchery stocks. The supplementation programs within these populations are integrated conservation and augmentation programs with a role in providing commercial and sport fishing opportunities as well as sustaining the naturally spawning population in viable numbers. Annual releases are moderate to large (100,000-600,000).

*Type 5: Any free-living salmon*

Type 5 designations are concentrated in the northern Oregon coastal populations of coho: Nehalem, Tillamook, Salmon, and Siletz (Table 1). Though all four populations have active supplementation programs, these designations are different than Type 4 in that they are isolated augmentation programs. Although the hatcheries may add to the viability of the populations, their primary role is to support fishing opportunities. In NOAA fisheries' proposed listing of the Oregon coastal coho ESU (Federal Register Notice 2004), all but one (North Fork Nehalem Stock 32) of the hatchery stocks from these populations were excluded.

| Population | Type | Percent Hatchery in Spawning Population (2000-2003) | Reason for Designation | Hatchery/ Operator |
|---|---|---|---|---|
| Necanicum | III | 4 | Releases 1990-91 (80,000 annually), excess fry releases 1992, 1998, 2002 (20-80,000) | |
| *Nehalem | V | 7 | Domesticated stock, isolated augmentation program (200,000 annually) | Nehalem (ODFW) |
| *Tillamook | V | 4 | Domesticated stock, isolated augmentation program (180,000 annually) | Trask (ODFW) |
| Nestucca | II | 2 | Moderate Releases 1990-92 (45,000 annually) | Cedar Creek (ODFW) |
| *Salmon | V | 83 | non-local broodstock, active isolated augmentation program (180,000 annually) | Salmon River (ODFW) |
| *Siletz | V | 13 | Active isolated augmentation program, moderate releases, domesticated stock (40,000 annually) | Siletz (Confederated Tribes of Siletz Indians) |
| Yaquina | III | 1 | Large release in 1990 from private hatchery (2,833,986), moderate ODFW releases 1991-97 (400,000 annually) | Yaquina Bay (private) |
| Beaver | II | 11 | No hatchery releases between 1990 and 2003, strays from Yaquina releases | |
| Alsea | III | 4 | Large releases (>1,000,000 annually) stopped in 1998, No releases since 1998 when the Fall Creek hatchery was decommissioned | Alsea (ODFW)<br>Fall Creek (ODFW) |
| Siuslaw | III | <1 | Moderate to small hatchery releases (6,000-300,000 annually) between 1990 and 1998 | |
| Siltcoos | II | 0 | One release (1,500) in 1997 | |
| Tahkenitch | II | 0 | Releases (2,000) in 1993 and 1994 | |
| Lower Umpqua | III | 5 | No releases since 2000, prior releases small (<100,000 annually) | STEP Facilities |
| Upper Umpqua | IV | 40 | Active integrated augmentation and conservation, large releases annually (600,000) 1/3-1/2 of broodstock from naturally spawning population | Rock Creek (ODFW) |
| Tenmile | II | 0 | Moderate to large releases between 1990 and 1994 (120,000-700,000 annually) | |
| Coos | IV | 2 | Prior to 1990 private hatchery releases as high as 12,000,000 annually, Current releases from Coos hatchery approximately 150,000 annually, Active integrated conservation augmentation program 30% natural broodstock | Coos (STEP) |
| Coquille | IV | 6 | Active integrated conservation augmentation program 30% natural broodstock, releases 100,000 annually | Bandon (ODFW)<br>STEP facilities |
| Floras | III | 2 | Unfed fry releases 1990 through 1999 (15-60,000 annually) | |
| Sixes | II | 0 | No supplementation, high likelihood of impact from strays due to small population size | |

**Table 1: Designations of types of coho according to current and historical supplementation and percent hatchery spawners in naturally spawning populations of coho on the Oregon Coast.**

* One or more hatchery stocks in the population were not included in NOAA Fisheries 2004 proposal for listing

## Section 5: Conclusions

The debate over defining what is meant by a "wild" salmon is more than semantic nuances and has substantial policy significance. Whether a definition of wild is selected from a suite of options as proposed here, or whether an alternative approach is deemed better suited, a method for overcoming the definitional confusion in the wild/hatchery controversy is essential. To do this, it is necessary to present policy makers with a method for explicitly resolving the controversy.

Salmon policy could be at a turning point in the Pacific Northwest. Traditionally, ODFW has managed Oregon coastal coho populations as a metapopulation, but with the recent changes in hatchery management, strategies have become focused on individual populations of coho at the watershed level. While it will always be necessary to evaluate each basin's contribution to the entire coastal coho metapopulation, more locally focused goals might be easier to assess and achieve given the diverse range of management goals for coastal coho and allow for greater diversity in management techniques.

Recognizing the need for specific goals for each of the 19 coho populations on the coast, the approach proposed here would push managers and policy makers to consider the most fundamental aspects of the salmon recovery problem. When faced with a range of options, policy makers will need to carefully and explicitly consider their objectives before proceeding with a definition of wild because the selection ultimately reflects a preferred policy goal.

Several north coast stocks (Nehalem, Tillamook, Salmon, and Siletz) were being managed for Type 5 salmon while the central Oregon coast was predominantly assigned Type 2 or 3 designations (Yaquina, Beaver, Alsea, and Siuslaw) and the southern Oregon coast had more Type 4 designations (Upper Umpqua, Coos, and Coquille). Thus, the north coast appears to be managed with emphasis on enhancing fishing opportunities, the central coast is managed to minimize the effects of hatchery fish on naturally spawning populations, and the south coast is managed for both fishing and the protection of naturally spawning salmon. The traditional and simple dichotomous split of salmon into either hatchery or wild is inadequate to describe such a complex management scheme. The continuum approach to defining what constitutes a wild salmon is offered as an alternative.

**Bibliography**

Bayer, R. D. 1989. The cormorant/fisherman conflict in Tillamook County, Oregon. Studies in Oregon Ornithology No. 6.

Brannon, E. L. 1993. The perpetual oversight of hatchery programs. Fisheries Research 18(1-2):19—27.

Brannon, E. L., D. F. Amend, M. A. Cronin, J.E. Lannan, S. LaPatra, W.J. McNeil, R.E. Noble, C.E. Smith, A.J. Talbot, G.A. Wedemeyer, and H. Westers. 2004. The Controversy about Salmon Hatcheries. Fisheries 29(9): 12—31.

Chilcote, M. 2005. Personal Communication.

CSRI (Coastal Salmon Restoration Initiative). 1997. The Oregon Plan Executive Summary and Overview. Oregon Water Resources Department. Salem Oregon.

ESA (Endangered Species Act). 1973. Title 16 U.S.C.A.

Federal Register Notice. 2004. Endangered and Threatened Species: Proposed Listing determinations for 27 ESUs of West Coast salmonids; proposed rule. Vol. 69, No. 113 pp33102—33179.

Fleming, I. 2004. Personal Communication.

Fuss, H. J. 1998. Hatcheries are a tool: they are as good or as bad as the management goals that guide them. Columbia River anadromous salmonid rehabilitation and passage symposium, Aquaculture Research Institute, University of Idaho.

Goodman, M. L. 1990. Preserving the genetic diversity of salmon stocks: a call for federal regulation of hatchery programs. Environmental Law 20:111.

Huntington, C. W. 1996. A survey of healthy native stocks of anadromous salmonids in the Pacific Northwest and California. Fisheries 21(3): 6—14.

Independent Scientific Group (ISG). 1996. Return to the River: Restoration of salmonid fishes in the Columbia River. Northwest Power Planning Council. Portland, Oregon.

Irvine, J.R. 2005. Canada's Wild Pacific Salmon Policy (WSP) and the Maintenance of Diversity. Proceedings of the World Fisheries Conference. Vancouver, BC.

Lackey, R. 2003. Pacific Northwest Salmon: Forecasting Their Status in 2100. Reviews in Fisheries Science 11(1): 35—88.

Lackey, R. 2004a. Normative Science. Fisheries 29(7): 38—39.

Lackey, R. 2004b. Wild Salmon in Western North America: The Historical and Policy Context. Chapter 2 *in* R.T. Lackey and D.H. Lach, editors. Salmon Project 2100: Options for Sustaining Wild Salmon Runs. Environmental Protection Agency, Corvallis, Oregon.

Lannan, J. E. 2002. Abundance and productivity of naturally spawning Oregon coastal coho salmon (*Oncorhychus kisutch*) in rivers with and without hatchery stocks. Hatchery reform: the science and the practice. E. L. Brannon and D. MacKinlay. Vancouver, Canada, International Congress on the Biology of Fish. Congress 2002: 107—116.

Lewis, M. 2005. Personal Communication.

Lichatowich, J. 1999. Salmon Without Rivers: a History of the Pacific Salmon Crisis. Washington, District of Columbia, Island Press.

Meengs, C. and R. Lackey 2005. Estimating the size of historical Oregon salmon runs. Reviews in Fisheries Science 13: 51—66.

Myers, R. A., S. A. Levin, R. Lande, F.C. James, W.W. Murdoch, and R.T. Paine. 2004. Hatcheries and Endangered Salmon. Science 303:1980.

NFHRP (National Fish Hatchery Review Panel). 1994. Report of the National Fish Hatchery Review Panel. The Conservation Fund, Arlington, Virginia

NFS (Native Fish Society). 2002. Native Wild Fish Conservation Policy Criteria Wild Fish Management Goals. Available: www.nativefishsociety.org/docs/Wild%20Fish%20MGT%20Goals.htm. (April 2004).

Nickelson, T. 2003. The influence of hatchery coho salmon (*Oncorhynchus kisutch*) on the productivity of wild coho salmon populations in Oregon coastal basins. Can. J. Fish. Aquat. Sci. 60:1050—1056.

NRC (National Research Council). 1996. Upstream: Salmon and society in the Pacific Northwest. Committee on Protection and Management of Pacific Northwest Anadromous Salmonids, National Academy of Science, Washington, D.C.

ODFW (Oregon Department of Fish and Wildlife). 1985. Coho Salmon Plan Status Report. Oregon Department of Fish and Wildlife.

ODFW (Oregon Department of Fish and Wildlife). 2003. Fish Hatchery Management Policy. Oregon Department of Fish and Wildlife.

ODFW (Oregon Department of Fish and Wildlife). 2005a. Coho estimates and occupancy (unpublished data). Oregon Department of Fish and Wildlife.

ODFW (Oregon Department of Fish and Wildlife). 2005b. Draft Hatchery Management Report. Oregon Department of Fish and Wildlife. Salem, Oregon.

ODFW (Oregon Department of Fish and Wildlife). 2005c. Draft Oregon Coastal Coho Assessment Part 2: Viability Criteria and Status Assessment of Oregon Coastal Coho. Oregon Department of Fish and Wildlife. Salem, Oregon.

PFMC (Pacific Fisheries Management Council). 2003. 2002–2003 Annual Report, Pacific Fisheries Management Council, Portland, Oregon.

Reisenbichler, R., S. Rubin, L. Wetzel, and S. Phelps. 2004. Natural Selection after release from a hatchery leads to domestication in steelhead, Oncorhynchus mykiss. Pages 371—383 *in* Stock Enhancement and Sea

Ranching: developments, pitfalls, and opportunities. K. M. Leber, H. L. Blankenship, S. Kitada and T. Svåsand. Oxford, Blackwell Publishing Ltd.

Smith, C. L., J.D. Gilden, J. S. Cone, and B.S. Steel, 1997. Oregon Coastal Salmon Restoration: Views of Coastal Residents. Oregon Sea Grant, ORESU-S-97-001.

Wahle, R. and R. Pearson. 1987. Artificial Propagation of Coho Salmon, Oncorhynchus kisutch, in the Mid-Columbia River System. Marine Fisheries Review 46:3.

Wahle, R. and R. Smith. 1979. A historical and descriptive account of Pacific Coast anadromous salmonid rearing facilities and a summary of their releases by region, 1960–1976. NOAA Technical Report NMFS.

Wilkinson, C. 1992. Crossing The Next Meridian. Washington, D.C., Island Press. 175–218.

## Definitions:

**Metapopulation**: *a group of individually isolated subpopulations. On the Oregon coast there are 19 such subpopulations that make up the Oregon coastal coho metapopulation.*

**Supplementation**: *the release of an artificially spawned salmon for the purposes of conservation.*

**Augmentation**: *the release of an artificially spawned salmon for the purposes of supporting fishing.*

**Evolutionarily Significant Unit (ESU)**: *An evolutionarily distinct population as defined by the National Oceanic and Atmospheric Association. The Endangered Species Act allows the responsible agency to list evolutionarily distinct populations as threatened or endangered without listing the entire species.*