Restoring Wild Salmon to the Pacific Northwest: Chasing an Illusion?[1]

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16. Abstract: Throughout the Pacific Northwest (Northern California, Oregon, Idaho, Washington, and the Columbia Basin portion of British Columbia), many wild salmon "stocks"(a group of interbreeding individuals that is roughly equivalent to a "population") have declined and some have extirpated. There have been substantial efforts to restore some runs of wild salmon; few have shown much success

Society's failure to restore wild salmon can be described as a policy conundrum that is characterized by: (1) claims by nearly everyone to be supportive of restoring wild salmon runs: (2) competing societal priorities which are at least partially mutually exclusive: (3) the region's rapidly growing human population and its pressure on all natural resources (including salmon and their habitats); (4) entrenched policy stances in the salmon restoration debate, usually supported by established bureaucracies; (5) society's expectation that experts can solve the salmon problem; (6) use of experts and scientific "facts" by political proponents to bolster their policy positions; (7) inability of salmon scientists to avoid being placed in particular policy or political camps; and (8) policy positions that are couched in scientific terms or scientific imperatives rather than value-based societal preferences.

Even with definitive scientific knowledge - and scientific knowledge will never be complete or certain - restoring most wild salmon runs in the Pacific Northwest would be an arduous and unlikely proposition. Concurrent with the substantial economic costs and social disruption required for any credible attempt at widespread restoration, is a questionable plausibility of ultimate success. Given the appreciable known costs and the dubious probability of success, candid public dialog is warranted to decide whether restoration is an appropriate, much less feasible, public policy objective. Provided with a genuine assessment of the necessary economic costs and social implications required for restoration, it is questionable whether a majority of the public would opt for the Draconian measures that are apparently necessary for restoring many runs of wild salmon.

Though the 21st century, I conclude there will continue to be appreciable annual variation in the size of salmon runs, accompanied by the decadal trends in run size caused by cyclic changes in climate and oceanic conditions, but many, perhaps most, stocks of wild salmon in the Pacific Northwest likely will remain at their current low levels or continue to decline in spite of heroic, expensive, and socially turbulent attempts at restoration. Thus it is likely that society is chasing the illusion that wild salmon runs can be restored to the Pacific Northwest without massive changes in the number and lifestyle of the human occupants, changes that society shows little willingness to seriously consider, much less implement.

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1. Introduction

Many populations of wild salmon in the Pacific Northwest (northern California, Oregon, Idaho, Washington, and the Columbia Basin portion of British Columbia) are declining (Netboy, 1980; Cone and Ridlington, 1996; National Research Council, 1996; Lackey 1999a; Lichatowich, 1999). There have been many costly efforts to protect and restore wild salmon, but the trajectory for the total number of wild salmon remains downward (Huntington *et al.*, 1996; Lichatowich, 1999). Public institutions seem to be unable, or at least unwilling, to act in a way to protect or restore wild salmon runs (Lee, 1993). Virtually no one is happy with the current situation, yet few recognize the connections between individual and societal choices, and the current and future status of salmon. Thus, there is a policy conundrum: salmon ostensibly enjoy universal public support, but society has been unwilling to arrest their decline, much less restore depleted runs (McGinnis, 1994, 1995).

Salmon restoration symbolizes a class of contentious, socially wrenching issues that are becoming increasingly common in the Pacific Northwest as demands increase on limited ecological resources (Lackey, 1997, 1999a). These ecological issues share a number of general characteristics: (1) *complexity* – there is an almost unlimited set of options and tradeoffs to present to officials and the public (Taylor, 1999); (2) *polarization* – these issues tend to be extremely divisive because they represent a clash between competing values; (3) *winners and losers* – some individuals and groups will benefit from each choice, while others will be harmed, and these tradeoffs are well known; (4) *delayed consequences* – there is no immediate "fix," and the benefits, if any, of painful concessions will not be evident for many years, if not decades; (5) *decision distortion* – these are not the kinds of policy problems that democratic institutions address smoothly because it is very easy for advocates to appeal to strongly held values; and (6) *ambiguous role for science* – scientific information is important but usually not pivotal in evaluating policy options because the selection by society of a policy option is inherently driven by value (political) judgments. Further constraining the role of scientific information is widespread public skepticism over its veracity because much of it is tendered by government agencies, industries, and myriad interest groups, each of which has a vested interest in the outcome of the policy debate and often vigorously promulgates "science" that supports its policy position.

The Pacific Northwest salmon restoration conundrum is characterized by a series of observations: (1) nearly everyone claims, at least superficially, to support maintaining or restoring wild salmon runs (Smith and Steel, 1997); (2) competing societal priorities exist, many of which are at least partially mutually exclusive (Michael, 1999); (3) the region's rapidly growing human population creates increasing pressure on all natural resources (including salmon and their habitats) (National Research Council, 1996; Salonius, 1999); (4) policy stances in the salmon debate are solidly entrenched and usually supported by well established bureaucracies (McEvoy, 1986); (5) society expects salmon experts to help solve the salmon problem (Lackey, 1999b); (6) each of the many sides of the political debate over the future of salmon employ salmon experts and scientific "facts" to bolster its argument (Smith, *et al.*, 1998); (7) it has proved to be nearly impossible for salmon scientists to avoid being categorized as supporting a particular policy position; and (8) many advocates of policy positions couch their positions in scientific terms rather than value-based preferences (Lackey, 1999b). As is typical in all fields of science, fisheries scientists promulgate legitimate, but often different, interpretations of the same set of data. Such scientific controversies may further confuse policy discussions.

For those who place a high value on maintaining runs of wild salmon, it is easy to conclude that conflicting societal priorities and technical limitations preclude a rational, positive resolution (Lang, 1996). Regardless, choices are being made – even the "no action" option is a *status quo* policy choice. The choices may not be the "best" ones (*best* defined here as the desires of the majority being implemented without unexpected consequences), but *choices* are being made.

My purpose is to provide the ecological, societal, and policy context for the current state of wild salmon populations in the Pacific Northwest and the options for their restoration. Most debate in salmon restoration is fundamentally a clash between competing values and preferences, but a certain amount of scientific information is required to appreciate the policy issues (Scarnecchia, 1988). Unfortunately, it is easy to concentrate on discussions of science because they encompass the training and comfort zone of salmon technocrats, but such diversions often mask the necessary dialog about the values and economic preferences society has adopted or may adopt. Therefore, I will constrain the description of the state of scientific knowledge to that required to scrutinize salmon policy.

Authentic options to reverse the decline of wild salmon, and especially to restore *depleted* runs, would be socially disruptive, economically costly, and ecologically equivocal (Michael, 1999). Throughout this article, however, I have attempted to be policy *relevant*, but not to advocate any particular policy option.

2. Salmon Biology

Pacific salmon are arguably the most studied group of fishes in the world. The massive amount of scientific knowledge available is a reflection of the economic, recreational, and cultural importance of salmon, both currently and historically. Many gaps and uncertainties remain, however, in our understanding of the biology of Pacific salmon.

There are seven species of what are classically labeled "true" Pacific salmon (Groot and Margolis, 1991). All seven are found naturally on the Asian side of the Pacific Ocean, but only five (chinook, coho, sockeye, chum, and pink) are found on the North American side (Lichatowich, 1999). There are also two species of sea-running trout (rainbow or steelhead and cutthroat) that have similar life histories and are often lumped with the five North American true salmon and treated as "Pacific salmon." The main practical difference between true salmon and sea-running trout is that true salmon die after spawning, but not all sea running trout do (Pearcy, 1992). Because the two sea-running trout and the five true Pacific salmon have similar life cycles (and are part of the salmon restoration policy debate), I will label them all as *Pacific salmon* (chinook, coho, sockeye, chum, pink, steelhead, and sea run cutthroat). Several species of Pacific salmon have been introduced elsewhere (*e.g.*, the Great Lakes, New Zealand, and Norway) and have established populations, but these are not considered here.

Pacific salmon are native to California, Oregon, Washington, Idaho, Montana, British Columbia, Yukon, Northwest Territories, Alaska, the Russian Far East, Korea, China, and Japan (Groot and Margolis, 1991). Their overall distribution has varied over the last several thousand years, mostly caused by climatic shifts, but the *approximate* distribution has been relatively constant (Chatters, 1996). Prior to 4,000 years ago, however, the distribution of Pacific salmon was substantially constrained by the residual influences of the last ice age. At certain periods in history, they were even found in Baja California and Nevada. Even today, it is evident that the distribution of salmon is far from fixed (McLeod and O'Neil, 1983). It is possible, for example, that there will be a range extension of Pacific salmon in the arctic areas of North America (Salonius, 1973). If, as many scientists expect, northern climates warm in the 21st century, such a range extension is probable.

Pacific salmon are *anadromous* – that is, they migrate from the ocean to freshwater, spawn, and, a few months to a few years after hatching, the young migrate to the ocean, where they spend from one to several years (Groot and Margolis, 1991; Meehan and Bjornn, 1991). Wild salmon almost always return to their parental spawning ground, but a small percentage of each run strays and spawns in a different location. Fidelity to the parental stream is important to assuring long-term fitness of the breeding population to a particular environment. Straying, on the other hand, allows salmon to colonize new areas, or areas where salmon runs have been lost. Because only a small *percentage* of salmon stray, the rate of expansion of the distribution is typically slow if the *number* of salmon is low, usually requiring from decades to centuries for salmon to occupy empty habitats or to re-occupy those habitats that have been restored.

The migrations of salmon vary greatly among species (Groot and Margolis, 1991; Pearcy, 1992). They may spawn in very short coastal rivers, even in estuaries, or traverse thousands of kilometers to the headwaters of the Sacramento, Columbia, Fraser, Yukon, Mackenzie, and other large rivers. Salmon of some species, such as sockeye, swim far out in the ocean, followed by a long ascension of a river to reach natal spawning grounds. Others, including anadromous cutthroat trout, stay close to the coast throughout the ocean portion of their lives.

Each salmon species is composed of many *stocks* – defined as self-perpetuating populations that spawn generation after generation in the same location (Nehlsen *et al.*, 1991). Stocks are adapted to the specific "local" environment by inherited biological attributes, such as timing of migration and spawning, juvenile life history, and body size and shape. Local environmental or watershed conditions are often highly variable, so a stock must have the ability to respond to sometimes drastic environmental changes (Bisson *et al.*, 1997). Debate over the "extinction" of wild salmon is usually focused on decline or loss of salmon *stocks*, not salmon *species*. Some *stocks* of salmon have been extirpated, but it is extremely unlikely that any *species* of salmon will disappear in the foreseeable future.

3. Salmon Population Trends

In general, the 150-year trajectory of wild salmon numbers is downward south of the Fraser River, British Columbia, but assessing the extent of the decline is difficult. Indeed, even determining the number of stocks is challenging (National Research Council, 1996; Lackey 1999a).

The number of salmon stocks in the Pacific Northwest is unknown, because of lack of biological data and also because of ongoing scientific debates about the level of genetic distinctiveness appropriate to define a stock. Defining a stock is far from simply a scientific exercise; it has major policy ramifications because if a stock is considered a "distinct" population, it must be treated as a full "species" under government and court interpretations of the U.S. Endangered Species Act (Waples, 1995; Dodson *et al.*, 1998). Unfortunately, the Endangered Species Act does not specify how population "distinctiveness" shall be assessed, an omission that has fostered considerable confusion and debate in the Act's application in salmon policy. For example, using a standard and fairly broad definition of a stock ("a group of interbreeding individuals that is roughly equivalent to population"), the number of stocks in the Pacific Northwest is in the tens of thousands. Thus, if each stock was considered a "distinct" population, potentially subject to legal protection as a "species" under the Endangered Species Act, the ramifications for society would be profound.

Genetic variation is important to maintaining the viability of salmon species because genetic variation represents its evolutionary potential. Some scientists argue that protecting *every* stock may not be necessary to preserve sufficient genetic variation to sustain each species. For example, the concept of "evolutionarily significant unit" (ESU) was fashioned to describe a salmon "meta-population" whose loss would be *significant* for the genetic or ecological diversity of salmon species (Waples, 1995). The use of ESUs as the unit of concern in salmon restoration has been criticized because there is no standard amount of significant "difference" among populations or stocks that is necessary to identify ESUs (Dodson *et al.*, 1998). Decisions about what constitutes "significance" and about the tradeoffs implicit in protecting ESUs are largely societal decisions that cannot be based on scientific grounds alone (National Research Council, 1996). Some challenge even the premise that it is possible to judge credibly the evolutionary significance of one spawning aggregate against that of another (Mundy *et al.*, 1995).

Decisions on the restoration of salmon will never be based solely on biological information (Dodson *et al*, 1998). Social, ethical, legal, and economic factors will also determine the restoration effort. Therefore, a biological unit of concern, the "operational conservation unit" (OCU) has been proposed (Dodson *et al*, 1998). The decision as to what aggregate of salmon ESUs will constitute a single OCU is based on socio-economic tradeoffs. In some cases ESUs might be synonymous with OCUs.

Beyond concerns about the effect of declining salmon runs on genetic diversity, there is the less obvious role salmon play in providing marine-derived nutrients to watersheds, particularly the upper portions of watersheds (Gresh *et al.*, 2000). The death and decay of salmon after spawning annually results in the release of nutrients. Large runs of salmon provide an important source of nutrients, especially in low-nutrient areas such as the headwaters (Cederholm *et al.*, 1999). Because of the dramatic decline in the size of wild salmon runs in the Pacific Northwest, it is estimated that the amount of marine-derived nitrogen and phosphorous now delivered to the region's watersheds is less than 10% of its historic level (Gresh *et al.*, 2000).

Another important ecological role that salmon play is providing food to terrestrial animals (Willson *et al.*, 1998). Many species of mammals, birds, and fish prey on salmon while they are in freshwater habitats. Predators feed on salmon at every stage in their life cycle: egg, fry, smolt, immature adult, and returning spawners. When the size of salmon runs are dramatically reduced, there is an effect, although not well understood, on the predator populations.

Many efforts have been undertaken to quantify the extent of the decline of wild salmon in the Pacific Northwest. For example, in reviewing current knowledge, Nehlsen *et al.* (1991) concluded that over 200 salmon stocks in California, Oregon, Idaho, and Washington are at moderate or high risk of extinction; that is, extirpation is likely unless something changes rapidly. An assessment (using somewhat different criteria) of British Columbia and Yukon stocks (Slaney *et al.*, 1996) identified over 702 stocks at moderate or high risk. Across the Pacific Northwest, at least 100-200 stocks, are already identified as extinct, but the actual number may be much higher. Even allowing for considerable scientific uncertainty over the past, current, and future status of salmon stocks, it is clear that some have become extinct, some are going extinct, and many more are likely to go extinct (Huntington *et al.*, 1996).

The declines are widespread in the Pacific Northwest, but not universal (Huntington *et al.*, 1996). Declines are not limited to large, often highly altered watersheds such as the Sacramento and Columbia, but are also documented in many smaller rivers along the coast. Causes of the declines are numerous and vary by geography, species, and stock.

In California – the southern most extent of the current range of salmon – virtually all salmon stocks have declined to record or near-record low numbers since 1980 (Mills *et al.*, 1997). Another survey concluded that most California salmon stocks are extinct or "unhealthy" (Huntington *et al.*, 1996). A recent assessment of waters of the Central Valley of California found that most of the principal streams and rivers that historically supported chinook salmon runs still do, but nearly half of them had lost at least one stock, and several major streams had lost all their chinook salmon stocks (Yoshiyama *et al.*, 2000). Historical records document that for several major Central Valley streams and rivers, large salmon runs were severely reduced or extirpated in the 1870s and 1880s by hydraulic gold mining and blockage by dams (Yoshiyama *et al.*, 2000). Hatchery-produced chinook salmon constitute a substantial and increasing fraction of most runs in the Central Valley.

In Oregon, although there is considerable disagreement on specific stocks, the overall status of salmon stocks is mixed (Kostow, 1997). Stocks from coastal rivers generally have stable to declining numbers, but some stocks are seriously threatened with extinction. The absolute number of fish in most coastal wild salmon runs appears to be a small fraction of that of a couple of centuries ago (Huntington *et al.*, 1996). Wild salmon stocks from the Columbia watershed are generally doing poorly; an indeterminate number are extinct and many others are declining.

The status of wild salmon in Washington is also mixed. Of 435 wild stocks (salmon and steelhead), 187 were recently classified as healthy, 122 depressed, 12 critical, 1 extinct, and 113 of unknown status (Johnson *et al.*, 1997). Coastal and Puget Sound stocks were generally in better condition than were those occupying the Columbia watershed. Another survey, however, found only 99 healthy (defined as at least one third the run size that would be expected without human influence) stocks throughout the *entire* Pacific Northwest (Huntington *et al.*, 1996).

Not surprisingly, wild salmon have declined markedly in Idaho (Nemeth and Kiefer, 1999). Idaho salmon travel as far as 1500 km downstream as smolts to reach the ocean, and eventually must return the same distance to reach natal spawning grounds to reproduce. Dam construction in the lower Columbia and Snake rivers has impeded salmon migrating to and from Idaho by converting a free-flowing river into a gauntlet of eight dams and reservoirs (Nemeth and Kiefer, 1999). The decline has been especially sharp during the last three decades (Hassemer *et al.*, 1997).

Assessments of British Columbia and Yukon salmon stocks show mixed results. Overall abundance of salmon in the Fraser River watershed decreased sharply from the levels of the late 1800s and early 1900s, although the most recent four decades (up to the early 1990s) have shown an apparent upward trend (Northcote and Atagi, 1997). Similar patterns exist for much of British Columbia, although status varies by species. There appears to be a long-term decline, but there is considerable variation among species and over time. Of the 9,662 identified salmon stocks in British Columbia and Yukon, 624 were at high risk of extinction and at least 142 have disappeared in this century (Slaney *et al.*, 1996).

In southeastern Alaska salmon runs are generally in good condition (Baker, *et al.*, 1996). Catches in the 1990s were generally at record levels and the numbers of salmon reaching the spawning grounds was generally stable or increasing for all salmon species for which there was adequate data (Baker, *et al.*, 1996). The condition of salmon runs elsewhere in Alaska is also good: runs of wild salmon either show no trend or increasing trends over time, indicating that the high catch levels are not due to over-exploitation (Wertheimer, 1997).

Alaska now produces approximately 80% of the wild salmon harvested in North America (Wertheimer, 1997). Most Alaskan catches (and runs) increased since the late 1970s and reached or exceeded historic highs through the mid 1990s and even later (Kruse, 1998). In fact, the highest worldwide catch of Pacific salmon recorded in this century occurred in 1995 and was composed principally of the Alaska harvest (Beamish, 1999). A recent sharp reversal of record high returns in some of the largest salmon runs in Alaska may signal the beginning of a downward trend. The number of sockeye salmon returning to Bristol Bay, Alaska (the world's largest sockeye salmon fishery) declined 50% in 1997 (Kruse, 1998).

The size of salmon runs varies roughly inversely between the northern and southern halves of the distribution. When stocks in the southern half (northern California, Oregon, Washington, Idaho, and southern British Columbia), have low run sizes, runs in the northern half of the geographic distribution (northern British Columbia, Yukon, and Alaska) tend to be large (Pearcy, 1997; Hare *et al.*, 1999). This reciprocal relationship (Pacific Decadal Oscillation) appears to be driven by oscillating climatic conditions; the resultant effect on ocean currents and upwelling determines the abundance of food for salmon (and predators) in the oceanic environment, and thus has consequences for salmon during the ocean phase of their life cycles. As ocean conditions change, often abruptly, marine habitat that was ideal for salmon can rapidly become inferior (or *vice versa*). The Pacific Decadal Oscillation appears to repeat every 20-30 years (Downton and Miller, 1998; Hare *et al.*, 1999).

Aquaculture, growing fish in captivity, is well developed for salmon and trout. Thus, it is fairly easy to "farm" salmon in captivity and provide a steady, predictable supply to markets. As a result, salmon are inexpensive by historic standards and are readily available to consumers. Commercial quantities of salmon are grown in captivity in the Pacific Northwest, Scandinavia, Scotland, and Chile and provide markets with a continuous supply of fresh salmon. The biological risks of aquaculture (and hatcheries) to wild salmon will be summarized in a later section.

In summary, although no *species* of Pacific salmon is near extinction and, for retail consumers, salmon are readily available and fairly inexpensive; nonetheless, many *wild* stocks of salmon in the Pacific Northwest have been extirpated or are experiencing population decline.

4. Historical Ecological Context

Estimating the size of past salmon runs in the Pacific Northwest is useful because these estimates provide benchmarks to measure the current state of wild salmon stocks and the effectiveness of restoration efforts.

For assessing changes in salmon run sizes during the past 150 years, it is possible to use cannery records and current field surveys and harvest records to develop credible estimates (Gresh, *et al.*, 2000). Such analyses show major declines in the aggregate size of wild salmon runs in California, Oregon, and Washington, a smaller percentage decline in British Columbia, and no obvious change in Alaska (Table 1).

Estimating the size of salmon runs in the Pacific Northwest prior to the late 1800s is more difficult. Explorers and settlers in the early to mid 1800s reported "massive" salmon runs, but it is difficult to interpret such anecdotal information to create benchmark levels or to infer trends. Further complicating estimating run sizes is the observation that relatively low rates of salmon harvest (as occurred in the early to mid-1800s) will often result in higher net reproduction, and thus *larger* subsequent runs than would occur in the absence of harvesting (Chapman, 1986). Apart from any human influence, the size of salmon runs, however, has varied enormously over the past 10,000 years (Chatters, 1996).

Anthropological data are inexact, but it is fairly certain that at the end of the last Ice Age, 10,000 - 15,000 years ago, humans and salmon expanded into the Pacific Northwest (Pielou, 1991; Chatters, 1996). Until 7,000 to 10,000 years ago, many of the upper reaches of rivers were blocked by glacial ice. Eroding glacial deposits and low water flows limited the size of the salmon runs for the next several thousand years. Ecological conditions improved for salmon approximately 4,000 years ago, probably from better oceanic conditions and more favorable freshwater environments (Chatters, 1996).

Aboriginal harvests of salmon increased gradually over the 4,000 years prior to "European" contact, almost certainly reaching a level affecting runs in at least some rivers, especially toward the southern and eastern extent of the salmon distribution (Swezey and Heizer, 1977; Taylor, 1999). It is sometimes incorrectly assumed that aboriginal fishing may be dismissed as an insignificant influence on historic run sizes, but Taylor (1999), after reviewing the results of recent anthropological research, concludes:

> *Taken as a whole, the aboriginal fishery represented a serious effort to exploit salmon runs to their fullest extent. Aboriginal techniques could be frighteningly efficient, and in many respects they compare favorable to modern practices. Weirs blocked all passage to spawning grounds; seines corralled large schools of salmon; and basket traps collected without discrimination. Indians in fact possessed the ability to catch many more salmon than they actually did.*

Many Indian tribes possessed fishing gear that enabled them to catch salmon effectively in variety of settings and under a range of conditions. Their gear encompassed a spectrum comparable to that available to 19th century "industrial" fishermen who supplied salmon to canneries (Smith, 1979). There was, however, a major difference between the two groups of fishermen and many societies. Undoubtedly, for the Indian fishermen and the overall Indian population prior to 1500, a rough equilibrium existed between the size of the salmon catch and the region's human population level because the number of salmon that could be consumed, sold, or traded by Indians was constrained (compared to modern standards) by technical limitations in fish preservation, storage, distribution, and, most importantly, a *relatively* low human population on the order of a million people across the entire region.

Although aboriginal fishing may have had impacts on individual stocks, especially those in smaller rivers and streams (which are more vulnerable to the effects of fishing), the aggregate effect on salmon runs was low compared to the current situation (Schalk, 1986). Further, except for using fire to clear vegetation, aboriginals lacked the capability to greatly affect salmon habitat. In summary it is reasonable to conjecture that from roughly 4,000 years ago to approximately the 1500s, salmon runs likely fluctuated greatly, but the long-term trend was likely upward with runs reaching their highest levels within the past few centuries.

The 1500s marked a dramatic change in the most recent 4,000 year history of the salmon/human relationship in the Pacific Northwest. From the early 1500s through the mid 1800s, a series of human disease epidemics (caused by Old World diseases, principally smallpox, measles, whooping cough, mumps, cholera, gonorrhea, and yellow fever) decimated aboriginal human populations (Denevan, 1992; Harris, 1997; McCann, 1999); this reduction in the human population caused a significant decline in fishing pressure (Taylor, 1999). For example, the population of what is now British Columbia was more, possibly much more, than 200,000 prior to 1800 (Harris, 1997). Thus, the large salmon runs observed in the early to mid-1800s were likely a reflection of the general, long-term trend of improving (from a salmon perspective) ecological conditions, coupled with a curtailment in harvest due to the extraordinarily diminished human population.

5. Causes of the Decline

To understand the current state of wild salmon in the Pacific Northwest, a careful review of the region's recent history is essential.

Conditions overall for salmon in the Pacific Northwest began changing markedly starting in the mid to late 1800s (Netboy, 1980; Mundy, 1997; McEvoy, 1986; Robbins, 1996; Lichatowich, 1999). By the early 1800s, the number of salmon harvested Indians had been reduced due the drastic drop in their numbers, coupled with the breakdown in social structure. Thus, salmon runs were lightly harvested and, therefore, were very large when immigrants in substantial numbers began arriving in the 1840s. By the middle 1800s, the human population of the Pacific Northwest ceased declining, and began growing slowly because of immigration from eastern North America, Europe, and Asia.

The mid to late 1800s also saw the refinement and widespread adoption of more efficient fishing methods (traps, fish wheels, gill nets) and the development of techniques to efficiently process, preserve, and distribute the catch using steel cans (Smith, 1979). In addition to their abundance, consumer appeal, relative ease of capture, and amenability to mechanization of processing and preservation, salmon offered the allure of reliability. The timing and approximate size of annual salmon runs was dependable, so fishermen, canners, and distributors could plan with confidence.

The consequences of the massive increase in fishing pressure in the mid to late 1800s (coupled with other widespread human actions such as mining and logging in the Pacific Northwest) on many salmon stocks was massive and rapid, even though salmon runs in the early to mid-1800s were probably at their historical highs (Chapman, 1986). By 1900 many stocks were reduced below levels required to ensure reproductive success, let alone support fishing; some probably were extirpated.

The well documented history of the Columbia River "industrial" salmon fishery illustrates the dramatic effects intense, minimally regulated fishing:

> *" . . . the Columbia River canned salmon industry, which began in 1866 [was] by the late 1880s . . . the biggest salmon-producing area on the Pacific Coast. During the early 1900s, the salmon industry was Oregon's third largest, but by 1975 the amount of salmon canned dropped to a level less than the pack of 1867, the*

second year of the industry." (Smith, 1979).

Competition for salmon harvest has been severe throughout the 20th century; recreational, commercial, and Indian fishermen demanded a portion of dwindling runs and successfully pressured fisheries managers to sanction relatively high harvest levels (Smith, 1979; McEvoy, 1986; Taylor, 1999). Understandably, there was (and *is*) reluctance to reduce fishing pressure because the immediate economic and social consequences were real and often severe (McLain and Lee, 1996). Further, U.S. state and Canadian provincial fish and wildlife agencies, supported largely by the sale of fishing and hunting licenses, have a distinct bias toward maintaining a high level of fishing (Volkman and McConnaha, 1993).

The general pattern of rapidly increasing harvest and eventual over-exploitation seen with Pacific Northwest salmon, far from being an aberration, is typical in renewable natural resource management (Hilborn *et al.*, 1995). By the 1930s, and prior to completion of the Columbia River main-stem dams, salmon stocks were substantially reduced from the levels of the mid 1800s. For example, the significant drop in Columbia River salmon harvest around 1925 marked the beginning of a long salmon decline and coincided with a change in oceanic conditions for salmon from favorable to unfavorable (Anderson, 2000).

High harvest rates are not the only major cause of salmon decline. Dams were built on many rivers and streams in the Pacific Northwest for navigation, irrigation, power generation, and flood control (Reisner, 1993). Floods, for example, have been common and devastating; particularly devastating floods occurred in 1861, 1876, 1894, 1948, and 1964. Therefore, flood control, and associated dam construction, has been a societal priority for well over a century, even though flooding has long-term benefits to salmon stocks.

Dams impede passage of both returning spawners and outmigrating young fish. Moving salmon past dams has long been a challenge to fisheries managers. Some dams totally blocked salmon migration. In the Columbia Basin, for example, over one-third of the habitat formerly occupied by salmon is now blocked by dams. Further, dams alter several key characteristics of water, especially temperature, dissolved gases, sediment transport, and the quantity and timing of flow. Each dam caused changes in the aquatic environment that had adverse consequences, some small, others huge, for salmon, especially in view of their evolutionary selection for life in free flowing rivers.

Salmon runs also dwindled as agricultural development took place in the Pacific Northwest (Cone and Ridlington, 1996). Because most of the region is arid, and irrigation is necessary for economically viable farming, water diversions (and dams) for irrigation, coupled with wide-scale agricultural use of chemical fertilizers and pesticides, have contributed to reductions in salmon runs. While a substantial portion of the annual flow of the Columbia Basin is used for irrigation, the extent of water withdrawals from individual streams varies markedly. Therefore, the true effect of agricultural water use on salmon runs must be assessed on a local basis. Further, cattle and sheep grazing (and many other agricultural practices) can adversely affect salmon by degrading water quality and altering spawning and nursery habitat. Agricultural practices are especially crucial if the run size has already been reduced (Mundy, 1997).

Timber in the Pacific Northwest is of high commercial quality (especially in the Cascade and Coast Ranges) and there has been considerable economic incentive to use this natural resource. The harvest and transport (initially by water and later by an extensive system of forest and rural roads) of timber has also had adverse effects on salmon spawning and rearing. Logging and associated road construction (especially prior to widespread adoption of current best management practices and governmental regulation) can cause increased water temperature and sediment load, as well as many other changes that can, at least temporarily, decrease the quality of salmon habitat (Meehan and Bjornn, 1991).

The use of fish hatcheries has caused major problems for *wild* salmon (Hilborn, 1992; Waples, 1999). Pacific salmon can be easily spawned and raised under artificial conditions. Historically, fisheries managers typically focused on hatcheries as a tool to rebuild declining runs (mainly responding to the adverse effects caused by dams or overexploitation). Hatcheries were often successful in maintaining salmon runs that would not have otherwise survived, but hatchery programs have probably accelerated declines of *wild* salmon (National Research Council, 1996). Hatchery-produced fish may introduce diseases, compete with naturally spawned fish, and alter genetic diversity through inter-breeding, which affects the "fitness" of subsequent generations (Waples, 1999).

After evaluating the effectiveness of hatcheries, Hilborn (1992) concluded:

> *"Large-scale hatchery programs for salmonids in the Pacific Northwest have largely failed to provide the anticipated benefits; rather than benefitting the salmon population, these programs may pose the greatest single threat to the long-term maintenance of salmonids."*

However, Michael (1999) acknowledged that, at least for many areas of the Pacific Northwest, society should:

> *" . . . recognize that habitat has been so altered that the cost of producing meaningful numbers of wild anadromous salmonids is too high and that wild salmonids may become essentially extinct.*

In these areas there will be extensive artificial-production programs designed to provide desired levels of harvest."

From the late 1800s to the late 1900s, attitudes toward hatcheries have evolved from near universal support to widespread skepticism as more people became concerned with preserving *wild* salmon rather than maintaining runs using artificially spawned fish (Bottom, 1997; Taylor, 1999). Many individuals are now openly hostile to the use of hatcheries, contending that the 100 or so hatcheries releasing salmon into the Columbia River system actually worsen conditions for wild salmon. The counter argument is that hatcheries *can* maintain salmon runs, even in rivers where there is no other practical option (Michael, 1999).

Hatcheries can also cause a more subtle stress on wild salmon: the decline of wild stocks is often masked by the presence of hatchery-bred salmon, a situation that takes place even in near-pristine habitat (Bottom, 1997). Hatchery-produced fish mix with naturally spawned fish, resulting in simultaneous harvest ("mixed stock fisheries") of abundant hatchery fish and less common wild fish. It is difficult, impossible perhaps in practice, to harvest abundant hatchery salmon and concurrently protect scarce wild salmon. McGinnis (1994) bluntly concludes that

". . . hatchery production of salmon masks the decline of wild salmon, contributes to the genetic dilution and loss of wild salmon, and increases competition for limited freshwater and ocean resources on which wild salmon depend."

In an effort to permit continued fishing for relatively abundant hatchery salmon, while protecting depleted wild salmon runs, agencies sometimes permit the "mixed stock selective fishing." The basic approach is to mark (by removing a fin) each hatchery raised salmon; thus if an unmarked salmon is caught, it is assumed to be wild and must be released. If selective fishing performed as hoped, it would allow capture of abundant hatchery salmon, but simultaneously safeguard less abundant wild fish. Although conceptually appealing, the scheme has several practical weaknesses. The risk is that it causes additional mortality on wild stocks that already may be at perilously low levels. The reasons for the additional mortality on wild salmon are: (1) it does not work in situations where the harvest method (*i.e.*, gill netting and purse seining) results in the death of most captured salmon; (2) some fish die after being hooked, caught, and released (collectively called "hooking mortality"); (3) not all fishermen comply with the legal requirement to release unmarked fish ("non-compliance mortality"); and (4) illegal fishing is more difficult to police when some legal fishing is permitted ("poaching mortality"). Further, using selective fishing regulations in fisheries management is expensive because hatchery-produced fish are costly (to the taxpayer) to produce, marking *all* hatchery fish is labor-intensive and costly, monitoring the effects of fishing on wild stocks requires extensive field sampling, and law enforcement must be vigorous and continuous.

One especially troublesome development (from the perspective of proponents of salmon protection or restoration) has been the introduction of non-native fishes (exotics) including walleye, striped bass, American shad, brown and brook trout, small- and largemouth bass, bluegill, northern pike, crappie, catfish, and carp (Fresh, 1997) and the expansion in distribution of native species such as squawfish. As salmon habitats were altered by human actions and runs declined, some exotic and native fishes prospered and expanded their distribution and numbers. Once these other fishes establish thriving populations, coupled with habitats that are no longer favorable for salmon, it is extremely difficult for salmon to reestablish viable runs. Further, some agencies actively managed in favor of popular, exotic game species and indirectly abetted the decline of wild salmon (Taylor, 1999).

Most salmon spend the majority of their life in the ocean, not in freshwater environments, so the oceanic and coastal portion of their life cycle must also be considered in assessing the causes of the current declines (Pearcy, 1997). Oceanic factors play an important role in salmon production on both sides of the North Pacific Ocean (Pulwarty and Redmond, 1997). For example, the long-term pattern of the Aleutian low-pressure system appears to correlate with trends in salmon run size (Hare *et al.*, 1999). On shorter time scales, and depending on the salmon species, stock, and where individuals in the stock spend the majority of their life in ocean, El Niño and La Niña events may have detrimental or favorable effects. It is undisputed, however, that high quality freshwater habitat plays a critical role in the persistence of salmon stocks during periods of unfavorable ocean conditions (Lawson, 1993; Bisson *et al.*, 1997).

Climatic variations and change also affect the condition of salmon stocks (Pearcy, 1997; Pulwarty and Redmond, 1997), but as was the case with the influence of oceanic variations previously discussed, the type and extent of effects on salmon is rarely straightforward. Examples of climatic change in the Pacific Northwest are the severe winters of the 1880s when many range cattle were killed, the extreme droughts of the 1910s and 1930s when many farmers were driven off their land, and the general drought of the 1970s and 1980s when water use conflicts were exacerbated. Over the last hundred years three major climatic shifts have occurred (1925, 1947, and 1977) which significantly altered salmon survival in the Pacific Northwest (Anderson, 2000). The past three decades in the Pacific Northwest have been among the warmest and driest for hundreds of years. If future climatic change (*e.g.*, natural or human induced global warming) causes even more adverse conditions, then additional sections of the current range of Pacific salmon will likely be occupied by fishes better adapted to these altered habitats, exacerbating the competition faced by the remaining salmon (Lackey, 1999a).

Predators, especially by marine mammals, birds, northern squawfish, and lampreys, are often identified as contributing to the decline of salmon in the Pacific Northwest (Smith, *et al.*, 1998). For example, since the early 1970s the number of harbor seals and California sea lions has increased to near historical levels because harvest of these animals has been prohibited by U.S. and Canadian laws (Fresh, 1997). Because these animals congregate at river mouths, they are efficient in capturing returning adult salmon (National Research Council, 1996). Marine mammals can have significant effects on salmon runs, but they are not believed to be one of the overriding causes of the general decline of wild salmon stocks (Fresh, 1997).

Squawfish and birds, usually gulls, terns, and cormorants, tend to congregate around dam sites, and in some locations can consume large numbers of juvenile salmon (National Research Council, 1996). Caspian terns, a species that often congregates in large nesting colonies, have become well established on the lower Columbia (on islands created by deposition of dredge spoil) and are now a major local source of predation on young salmon migrating to the ocean. When considering all the causes of salmon decline, predation by marine mammals, birds, and squawfish may not be a dominant regional cause, but it can be a significant local factor, especially when salmon runs are low (National Research Council, 1996).

6. Theory of Fisheries Management

The decline of wild salmon in the Pacific Northwest occurred in the presence of a cadre, often substantial in number, of professional technocrats who were aware of the situation (Taylor, 1999). The negative consequences for salmon of mining, dam building and operation, road construction, water diversion, land reclamation, and pollution were recognized by fisheries scientists by the late 1800s. By the early 1900s the general limitations and shortcomings of salmon hatcheries, although less irrefutable, were documented in the professional fisheries literature (McEvoy, 1986).

As a formally organized profession, fisheries management has existed in North America for more than 125 years. The American Fisheries Society, for example, was incorporated in 1870. Since the mid to late 1800s, although rarely stated explicitly or even debated, nearly all efforts to manage fisheries have followed a simple management paradigm, called in the professional fisheries literature the "theory of fisheries management."

The core assumption in fisheries management theory is that all benefits (loosely defined as things that have value) derived from aquatic resources are accruable to man (Lackey, 1998a). "Benefits" often has a very broad definition in fisheries management. For example, even though most people in eastern North America never see a wild Pacific salmon, the *existence* of wild salmon still has value to them. The actual catch of salmon (be it recreational, commercial, or subsistence) and economic return on investment (boat, gear, and labor) are commonly measured individual and societal benefits, but neither is sufficient to capture the benefits derived from fishing.

Society may choose to protect none, some, or all salmon species, maintain various stocks at high or low levels, permit some stocks to disappear, or manage for species other than salmon; these decisions produce benefits to people — not simply tangible, consumptive benefits. *Consumptive* use of salmon (*i.e.*, harvesting fish) is only one of the benefits derivable from fisheries management. Other, nontangible benefits (*e.g.*, the fishing "experience") may be of equal or greater importance in terms of societal benefits (Roedel, 1975).

In general, the theory of fisheries management is a problem of "constrained optimization" and may be expressed as:

$$Q_{max} = f(X_1, X_2, \ldots, X_m \mid Y_1, Y_2, \ldots, Y_n)$$

where

Q = *some measure of societal benefit*

X = *a management decision variable (the vertical line reads "given")*

Y = *a societal or ecological constraint variable*

The theory might look imposing, but it is not conceptually complicated. It reads "the greatest (maximum) societal benefit (Q) from a fishery can be realized by manipulating a series of decision variables (Xs), *given* a set of constraints (Ys)." Controlled or partially controlled decision variables (Xs) are those regarded as fisheries management techniques (*e.g.*, selective fishing regulations, spawning ground improvement, predator control, dam alteration or removal, pollution abatement, etc.). Noncontrolled variables (Ys) are random or dependent on other factors (climate, ocean conditions, economic changes, societal attitudes, oil spills, etc.). Some variables, however, may overlap both categories. Recognizing constraint variables, the manager tries to select a series of decision variables that will maximize Q. Everything in management, whether it is biologic, economic, or social, fits into this theory.

Fisheries management traditionally attempts to maximize (within constraints) some measure of "output" from fisheries resources (Stephenson and Lane, 1995). Controversy over sustainability, protecting biological diversity, and protecting certain species/stocks, for example, is largely predicated on how society ranks or balances various constraint and decision variables. Q is a nebulous societal endpoint for which managers (and society) only have an array of surrogate measures such as number, weight, or size of fish caught, number of angler days provided, species or stocks preserved, ecosystems maintained in a desired state, cultural lifestyles maintained, or any of a number of economic or societal indices. Further hindering consensus on Q is the time dimension; short-term time frames often lead to very different management strategies than do longer-term ones. In fact, identifying *Q* is perhaps the pivotal challenge in fisheries management as is amply demonstrated in salmon management.

Setting societally appropriate fisheries management objectives is not a simple task (Sylvia, 1992; Stephenson and Lane, 1995). Because of the divisiveness of setting objectives in natural resource management, establishing explicit objectives tends to be neglected. It is easy to criticize this intentional oversight, but it often occurs for compelling reasons. Salmon managers, for example, may be unwilling to delineate publically explicit management objectives for fear that they will be violently opposed by some of the affected parties or, worse, may be shown to be unattainable in the absence of an ecological miracle (Fitzsimmons, 1996).

Managers may be unable to formulate objectives because of a number of constraints such as incomplete awareness of problems, incomplete knowledge of the intricacies of the problem, and inability to devote sufficient thought to the effort because of time, money, or manpower constraints. In spite of a vast literature on the subject, objective-setting methodology is not sufficiently defined and straightforward to be of use to most fisheries managers. Although virtually everyone acknowledges the importance of management objectives, the few sound techniques available are complex and laborious (Lackey, 1998a).

Who should set objectives – agency personnel, the general public, or a combination of the two? Historically, fisheries managers have used consultation between professionals in institutional (usually governmental) roles to set objectives (Smith, *et al.*, 1998). Critics term this an "elitist" planning process (Taylor, 1999), but it does have the advantage of allowing those who are trained and, presumably, best qualified and most knowledgeable to decree management objectives and make decisions to achieve those objectives. However, in a pluralistic society, most professionals now advocate, at least publicly, use of systematic public input in setting objectives (Smith, *et al.*, 1998).

One of the most urgent social needs in natural resource management is determining public needs and preferences (Smith and Steel, 1997), but providing the public with understandable and credible assessments of the consequences of various choices is equally important. Many of the failures of salmon management are attributable to the inability of managers to understand the desires of certain influential segments of the public, and their failure explain convincingly the impossibility of achieving some objectives (Stephenson and Lane, 1995). North American society may at one time have deferred to fisheries managers, but deference is not often the case now, and especially when professional salmons managers and scientists rarely appear to agree among themselves.

Historically, the most common objective has been to maximize pounds or numbers of fish on a sustained basis. This is usually referred to as MSY (maximum sustained yield) or, sometimes, equilibrium sustained yield. In the past few decades this approach has come under increasing criticism. Most criticisms focus one of several points: (1) protein or biomass output from a fishery is no longer the dominant societal benefit; (2) assuming a constant external environment (including the ocean) can no longer be justified as is typically done with MSY; and (3) "excess" spawning salmon provide an important ecological role in terrestrial ecosystems (Roedel, 1975; Bottom, 1997; Malvestuto and Hudgins, 1996; Willson *et. al.*, 1998). There are many variants of the MSY approach; these usually revolve around maximizing yield of certain species or stocks or maximizing catches of individuals of a certain size.

Desirable properties of MSY are that it is conceptually simple and that it is an objective-oriented approach to management and public policy. However, MSY has some inherent disadvantages, the main one being that catch is only one among the several measures of output (benefit) from a fishery. Catch is an important component of the total benefit, but *fishing* is also an important component. Numerous surveys have shown that many recreational anglers enjoy the fishing experience even though "fishing success" is less than what may be considered ideal (Hudgins, 1984). Other important aspects of recreational fishing, for example, are the perceived quality of the outdoor experience, the environment, and the sporting challenge. Specific elements of the benefits related to the actual catch are species caught, fish size, and the angling method.

Even in commercial salmon management, it is important to recognize that economic return is only part of the benefit derivable to fisherman (and thus to society)(Larkin, 1977). For many commercial fishermen, psychological benefits (lifestyle preferences and personal satisfaction) are major factors in job satisfaction. Many may regard commercial fishing as a rough, dangerous, demanding, undesirable vocation, but such types of work nourish strong, enduring bonds among the participants. Thus, salmon fishermen often continue fishing when economic argument alone would predict that they would stop.

Recreational salmon fishermen also receive psychological benefits that may exceed the tangible benefits received from catching fish. Unfortunately for salmon managers, there is no functional pricing system to value various recreational or commercial psychological factors, nor can such benefits be easily determined by market survey (Repetto and Dower, 1992). Aesthetics probably can never be accurately measured, but by identifying the variables associated with the angling experience and angler's perceptions of them, a reasonable approximation of aesthetics valuation might be obtained. Also, many societal benefits (*e.g.*, existence values, moral imperatives) from salmon management accrue to segments of society that do not fish. Even though such "non catch" benefits should be important in establishing salmon management objectives, their quantification is severely constrained.

Another approach to fisheries management is maximizing the "experience," including the elements of aesthetics or environmental quality. Whereas this sounds laudable and desirable, it is extremely difficult to apply in practice. Often referred to as optimum sustained yield (OSY), it has some of the characteristics of MSY but the meaning of OSY is ambiguous and it has tended to be regarded as a philosophical rather than a pragmatic approach to fisheries management (Roedel, 1975). More recently, some procedures have been developed to incorporate biological, economic, and social values into goal setting for fisheries management (Malvestuto and Hudgins, 1996).

A management goal, intermediate between MSY and OSY, is maximize some measure of angler use or the quality of the angling experience. Fishing "quality" is a nebulous parameter, but certain factors that contribute to the fishing experience can be delineated and sometimes measured. The number of potential variables is great, but if the key ones could be identified, the analytical challenge would be much reduced. Maximizing the diversity of angling opportunity, commonly used in agency management programs, is an example of this approach.

An unfortunate characteristic of fisheries management, true in the extreme for salmon management, is that active management does not start until a "problem" is apparent. The problem may be a precipitous decline in catch, the scarcity of preferred species or stock, or the potential extirpation of a species or stock. Thus, salmon management tends to be reactive, not proactive. As Crutchfield and Pontecorvo (1969) conclude in evaluating the history of management of Pacific salmon fisheries:

> *There is no record of a major fishery management scheme that was not introduced in an atmosphere of desperation after the evidence of severe depletion had become too obvious for any explanation other than over-fishing.*

Most ecosystems supporting salmon were already significantly altered and adversely affected by the time fisheries managers become involved. The options open to managers (and society) were thus significantly truncated. Under such circumstances, the role of a fisheries manager was (and is) to be the bureaucrat responsible for allocating a scarce and often declining natural resource.

7. Endangered Species Issues

Salmon policy and management has recently become much more complicated with the enactment and implementation of the Endangered Species Act as a major component (Rohlf, 1991; Smith, *et al.*, 1998). A spirited debate over the policy-effectiveness of listing subspecies such as individual stocks or groups of stocks (*e.g.*, evolutionarily significant units or distinct population segments) as threatened or endangered has dominated salmon policy debate through the 1990s. Some people (*e.g.* McGinnis, 1994) hail the Endangered Species Act as the needed stimulus to provide " . . . a major incentive to develop a comprehensive watershed-by-watershed effort to restore wild salmon populations." Others reject the Endangered Species Act as "feel good policy" based on "barbershop science."

There are many ethical, political, and scientific implications enveloping policies on threatened and endangered salmon that make it difficult to avoid becoming mired in the pros and cons of specific policy options. To some, the debate over declining salmon runs is simply a matter of choosing among options, similar to choices required for deciding energy, transportation, or international trade policies. Thus, agreement on a plan to "save" wild salmon would be achieved by following the classic political process of compromise and tradeoff.

Others view endangered salmon issues in the stark terms of right and wrong, moral and immoral, ethical and unethical. If a participant in the policy debate perceives the salmon decline issue as fundamentally a moral or ethical one, it is not realistic to expect a political compromise. Such strongly held policy positions mean that the ultimate resolution will be perceived unconditionally as win-lose.

Still others hold strong moral and ethical views on endangered salmon concerns, but view such issues through the prism of competing rights – the rights of the public *vs.* the rights of individuals. An example is the ongoing debate over the legal adjudication of situations where a public action constitutes a "taking" of private property and requires financial compensation to the owner. Society may conclude that preservation of salmon is important, but regulations to achieve this societal objective should not disproportionately burden particular members of society. The political argument is usually that no one should be required to *de facto* relinquish his private property without compensation caused by a "regulatory taking." The counter argument is, of course, that those individuals and segments of society that exacerbate the salmon decline or impede recovery ought to bear the cost of recovery.

It is not surprising that the debate over the Endangered

Species Act and its implementation relative to salmon restoration is characterized by truculent adversaries who denigrate the motives of other combatants. The fact is that the combatants do have different motives and that each policy choice involves winners and losers.

Some skeptics question how democratic institutions are to choose among salmon restoration options when the losers cede so much and there is little societal consensus except at the most general, abstract level. Others assert that we have *de facto* accepted the philosophy of those, a minority in their opinion, who hold it morally improper to extirpate a species or subspecies under any circumstances. Is compromise with mutually exclusive options possible? Can public policy be implemented when a "choice" can end up in court for what seems like an eternity? And what is so important to society about individual stocks, much less the emerging, but contentious concept of evolutionarily significant units, whatever those might be? Are critics correct in asserting that the Act is ordained to failure because the costs of complying with it sometimes fall heavily on private landowners who lose land, pay fines, face restriction on use of their property, or watch their investments and business ventures collapse? Or, are these simply groundless charges playing on people's skepticism of government?

In practice, the management consequences of the Act tend to be greatest on public lands, especially Federal lands. Supporters usually argue that, even if the consequences of the Act are painful, the pain is a necessary part of a last ditch effort to save listed species. But such "pain," whether current or anticipated, evokes political backlash to using the Endangered Species Act as a tool to protect and restore salmon:

> *"This is as much a human crisis as a salmon crisis. We must commit ourselves to restoring a balance between the interests of humans and of salmon, and must do so soon. We used to ask how we*

could save salmon without hurting people, but that compromised nature too often. The Endangered Species Act reversed the equation by blocking all development that threatened salmon, but that raised protests because the law ignored important human interests. Neither way has worked." (Taylor, 1999)

Arguments in support of the Endangered Species Act and similar legislation are often framed as moral assertions not amenable to easy compromise. There may be references to the importance of protecting species because of their "commodity" value or their use as "surrogates" for environmental quality, but the issue is inherently whether humans have (or should have) a right to drive a species, stock, or evolutionarily significant unit to extinction.

Others argue that historical perspective is required because species extinctions are not new in the Pacific Northwest. People have been moving to the region for the past 15,000 years and causing "problems" from the start (McCann, 1999). As recently as 10,000 years ago, the region supported mastodons, mammoths, giant sloths, giant armadillos, giant beavers, American camels, American horses, the American tiger, and the giant wolf – all are now extinct, probably due to a combination of hunting, climate change, and introduced diseases (Pielou, 1991; McCann, 1999).

While species (and stock) extinctions are not new in the Pacific Northwest, it is the rate and scale that are the issue today, as well as the fact that the causes are chiefly due to human actions. Salmon gene pools (stocks) that survived the Pleistocene glaciation have been eradicated within a few human generations. Only mighty events such as cataclysmic volcanic eruptions, colossal earthquakes, and severe climatic episodes such as droughts have previously caused salmon stock extinctions at the scale we observe today in the Pacific Northwest.

8. Ecosystem Health

A common lament about invoking the Endangered Species Act to protect or restore wild salmon is that it focuses protection and restoration efforts merely on species, stocks, evolutionarily significant units, or distinct population segments. In contrast, the concept of ecosystem health is an approach that is often advocated as superior to focusing on protecting remnant populations of declining species (*i.e.*, stocks of Pacific salmon) (Steedman, 1994; Gaudet *et al*, 1997). In most formulations of ecosystem health, the policy or management focus is the condition of the *entire* ecosystem, although individual species may be recognized as essential components of the ecosystem and, therefore, important to society (Rapport, 1998; Lackey, 2000).

Ecosystem health enjoys a wide following, especially among some of the popular press and some environmental advocacy groups (Gaudet *et al.*, 1997). Part of the appeal is that it appears to be a simple, straightforward concept (Ryder, 1990; Lackey, 2000). Applying the human health metaphor to ecosystems, it proposes a model of how to view ecological policy questions (Callicott, 1995). But, in practice, it has proven difficult to implement (Lackey, 1998b).

Ecosystem health, especially in the 1970s and 1980s, was often defined in nebulous terms – definitely not as clearly articulated constructs (Steedman, 1994). It was typically depicted as a broad societal aspiration rather than a precise policy objective. Lacking precise definition, it was difficult to consider the concept as a practical public policy tool. As the concept emerged from semantic ambiguity with more precise definition and description, it became a serious topic for discussion and, predictably, a lightning rod for conflict (Rapport, 1998).

The most alluring feature of the human health metaphor is that people have an inherent sense of personal health (Ryder, 1990). By extension, proponents argue that people instinctively envision a "healthy" ecosystem (*e.g.*, a forest, lake, pastoral landscape, or river replete with migrating salmon) as being pristine or at least having the appearance of minimal human alteration.

Many concepts of human health focus on the *individual* human, whereas ecosystem health considers the *ecosystem* as the unit of policy concern, as opposed to the individual animal or plant (Lackey, 2000). Concerns about *individual* animals – the typical focus of "animal rights" and "animal welfare" policy – are usually not the level at which *ecological* policy is debated.

There remains considerable variation and understanding in the concept being conveyed by the words "ecosystem health." Karr and Chu (1999), for example, reflect a common, but not universal, position that concepts of ecosystem *health* and *integrity* are fundamentally different. They define ecosystem *health* as the *preferred* state of ecosystems that have been modified by human activity (e.g., farm land, urban environments, airports, managed forests). In contrast, ecological *integrity* is defined as an *unimpaired* condition in which ecosystems show little or no influence from human actions. Ecosystems with a high degree of integrity are natural, pristine, and often labeled as the base line or benchmark condition.

The implementation of the concept of ecosystem health has been surrounded by controversy (Jamieson, 1995; Wicklum and Davies, 1995; Callicott, 1995; Belaoussoff and Kevan, 1998). Addressing questions of ecosystem health might appear to be a fairly scholarly, perhaps even arcane, activity, free from the political intrigue that dominates much of the science and policy underlying environmental management, but such is not the case. Wicklum and Davies (1995) suggest that the word "health" elicits powerful, positive images even if its meaning is ambiguous. Therefore, they argue, a precise understanding of the concept is essential because it is likely to be used, and given a variety of meanings, by policy advocates, politicians, bureaucrats, and the general public. In practice, it may fall to salmon technocrats to provide operational clarity to such perplexing, value-laden, normative concepts that appeal on an intuitive level to nearly everyone. Normative ecological concepts such as ecosystem health have become abstract perceptions, perhaps useful in general conversation, but impossible to quantify (Ryder, 1990).

Some (Shrader-Frechette, 1997; Kapustka and Landis, 1998) have counseled against using the concept of ecosystem health in communication to the public about environmental issues. To be sure, thoughtful discussions about ecosystem health and similar concepts are usually abstract, often contentious, and rarely lead to consensus, but is the use of the health metaphor even as a heuristic tool ill-advised? Kapustka and Landis (1998) posit that the metaphor is misleading and based on particular values and judgments, not an *independent* scientific reality.

Relative to salmon policy, most critics concede that, although the human health metaphor provides a simple heuristic framework for the decline of wild salmon and their possible restoration, it fails to capture the most contentious element of ecological policy – the decisive role played by competing individual and societal values and preferences. Further, it is prone to improper use by condoning, even encouraging, scientists and other technocrats to implicitly select which societal preferences will be sanctioned.

Whether current notions of ecosystem health will evolve sufficiently to overcome their inherent deficiencies in addressing the general decline of wild salmon, or the even the disappearance of specific stocks, is uncertain. Notions of ecosystem health currently offer limited practical guidance in reconciling the most divisive elements of salmon policy.

9. Ecosystem Management

To address the decline of wild salmon, management goals and approaches other than ecosystem health have been proposed, debated, and, in some cases, implemented. During the 1980s, a widespread concern surfaced that traditional approaches to managing renewable natural resources (including Pacific salmon) were not working well (McLain and Lee, 1996). At the same time, ecosystem management emerged, especially in the natural resource and land management agencies, as a popular, although philosophically imprecise, approach to managing natural resources (Grumbine, 1994; Stanley, 1995; Lackey, 1998b).

Ecological policy problems, for which ecosystem management is typically advocated as a solution, have several general characteristics: (1) fundamental public and private values and priorities are in dispute, resulting in at least partially mutually exclusive decision alternatives; (2) there is substantial and intense political pressure to make rapid and significant changes in public policy; (3) public and private stakes are high and there are substantial costs and substantial risks of adverse effects (some perhaps irreversible) to some groups regardless of which options are selected; (4) some ecological and sociological "facts," are highly uncertain; (5) the "ecosystem" and "policy problems" are meshed in a larger political framework such that "salmon" decisions will have implications outside the scope of the "salmon" problem (Lackey, 1998b). The policy problem of reversing the decline of wild salmon stocks possesses all the above characteristics and would appear, at least on the surface, a good candidate for adopting ecosystem management.

The diversity of the purported characteristics, definitions, and descriptions of ecosystem management provide some indication of the amorphous and evolving nature of the concept:

> "*Ecosystem management is not a rejection of the anthropocentric for a totally biocentric world view. Rather, it is management that acknowledges the importance of human needs while at the same time confronting the reality that the capacity of our world to meet those needs in perpetuity has limits and depends on the function of ecosystems.*" (Christensen, *et al.*, 1995)

> "*. . . there is no* a priori *imperative to include management for biodiversity, ecosystem health and integrity, and commodity production in every ecosystem management effort, and therefore to specify them in a general definition.*" (Wagner, 1995)

> "*The philosophy of ecosystem management requires asking ourselves what kind of a society, and correspondingly, what kind of relationship with nature we want. Patterns of politics suggested by ecosystem management include public deliberation of values toward the environment, cooperative solutions, and dispersion of power and authority. These are all avenues to lessen social hierarchy and domination. Through opening the value debate, fostering a sense of interdependence among humans, and renewing a sense of reason, the chains of social domination may be lessened.*" (Wallace *et al.*, 1996)

> "*A human community in a sustainable relationship with a nonhuman community is based on the following precepts: first, equity between the human and nonhuman communities; second, moral consideration for both humans and other species; third, respect*

for both cultural diversity and biodiversity; fourth, inclusion of women, minorities, and nonhuman nature in the code of ethical accountability; and fifth, that ecologically sound management is consistent with the continued health of both the human and the nonhuman communities." (Merchant, 1997)

"The application of ecological and social information, options, and constraints to achieve desired social benefits within a defined geographic area and over a specified period." (Lackey, 1998b)

"Full implementation of a policy of federal management and protection of ecosystems would extend the reach of federal regulators to all private land in the United States, increase regulatory burdens, and further restrict the economic use of public and private lands." (Fitzsimmons, 1998)

At least in North America, the ideas behind ecosystem management represent a predictable response to evolving societal values and priorities (Lackey, 1998b). Those values and priorities will continue to evolve, although their evolutionary direction is mostly unpredictable. Without major upheavals such as war, economic collapse, millennial earthquakes or volcanic eruptions, or the plagues caused by exotic organisms, the movement of social preferences toward the values and priorities of "affluent" people will probably continue. While ecosystem management operates within the reality of intensive alteration and use of nearly all formerly natural areas, paradoxically, high value is given to the non-consumptive elements of ecosystems such as pristineness. Most people want the benefits and affluence of a "developed" economy, but few want its factories, foundries, and freeways in their back yards.

There are other directions for ecosystem management that are less clear, but potentially more significant (Merchant, 1997;

Lackey, 1999c). At a major international conference, a statement from an audience member illustrates such a possible direction:

> *"It is time to change our [society's] charter with individuals. We have massive and critical problems with our ecosystems that cry out for immediate action because we have subordinated the collective good of society to the will of individuals. Personal freedom must be weighed against the harm it has caused to the whole of society, and more importantly to our ecosystems."*

A response to the statement from another member of the audience was equally instructive:

> *"Society and freedom are at greatest risk from those with the noblest of agendas."*

Ecosystem management will continue to be place-based because ecological policy problems must be bounded explicitly to make them tractable and geographical boundaries are the most pragmatic (Lackey, 1998b). A practical implementation problem in North America, however, is that in many locations much of the "place" is owned by individuals, not by society in the form of "public lands." By being place-based, the application of ecosystem management will become a focus for debates over private versus societal "rights." How does society balance the right of individuals (or Indian tribes, private organizations, and nongovernmental organizations) to be free from property seizure without compensation against the right of society to achieve a collective goal? Perhaps the concept of owning ecosystems (places) must yield to other "rights" for the greater collective good?

Ecosystem management is often described in terms of ecosystem health, ecosystem integrity, biodiversity, and sustainability — "scientific" words that have frequently served as surrogates for specific personal values and policy preferences (Lackey, 2000). Unless these terms are precisely defined and clearly separated from values and priorities, their utility in science or policy analysis is severely diminished. There are, for example, a variety of meanings and nuances submerged in the concepts of "sustainability" and "sustainable development" that are not widely appreciated, but have important ramifications for ecological policy (Dovers and Handmer, 1993).

There appear to be two policy trajectories for resolving the operational meaning of ecosystem management (Lackey, 1999c): (1) the first, and most likely to happen, is that the expression "ecosystem management" might be defined as functionally equivalent to the classic, anthropocentric natural resource management paradigm and merely reflect another stage in the evolution of societal values and preferences; (2) the other path is that "ecosystem management" will come to be the policy banner for an eco- or biocentric world-view that is closely tied to concepts of species egalitarianism, bioregionalism, democratization, and possibly local empowerment.

In summary, ecosystem management *may* be a revolutionary concept that results in a sea change in ecological policy and natural resource management, or it *may* end up as an evolution of existing, well-established approaches to natural resource management. Relative to its potential use in addressing salmon restoration, what distinguishes ecosystem management is its emphasis on the entire "ecosystem" occupied by salmon throughout the life cycle, as well as the postulate that humans are part of that ecosystem. Ecosystem management, unfortunately, offers no visionary path for salmon restoration, but rather serves to emphasize the interconnectedness of all the ecological and societal elements of the salmon decline/restoration issue (Lackey, 1999c).

10. Science and Salmon Policy

Even more than a new policy or management paradigm, any credible effort to restore wild salmon will require the active involvement of salmon technocrats (professional scientists who deal with salmon issues). Their appropriate role, however, is not often appreciated by the public nor by policy officials because providing policy-relevant, but policy-neutral, information is often more complicated than expected (Smith, *et al.*, 1998; Lackey, 1999b; Mills and Clark, 2000).

For the salmon technocrat, the debate over salmon policy takes place on a battlefield of seemingly intractable policy alternatives, complex and contentious scientific challenges, and confused roles. There are forceful advocacy groups representing commercial, recreational, and Indian fishermen, agricultural activities, various elements of the transportation sector, forest and range land users, electrical generators and users, natural resource management agencies, various segments of the environmental movement, endangered species and animal rights proponents, municipal and local governments, and a general public that is not aware of the implications and tradeoffs of the various policy options, in part attributable to superficial reporting by much of the media.

What role salmon technocrats should play in salmon policy is a time-honored discussion topic among technocrats and policy advocates (Cooperrider, 1996; Lackey, 1999b; Salonius, 1999; Mills and Clark, 2000). Some advise staying out of the policy arena; others bluntly encourage all technocrats to argue for those public policies they prefer.

Intuitively, the public and policy makers have a right to expect salmon technocrats to be honest in providing scientific information. While apparently uncomplicated, this principle is not as simple as it might appear. It is easy to avoid telling the entire truth about the ecological consequences of various salmon policy decisions and thus mislead people:

> *" . . . water managers have been asking fishery biologists to determine how to maintain salmon runs while damming rivers. Biologist dutifully proceeded to experiment with fish hatcheries, minimal flows, and so on, many of them knowing that such mitigations are virtually hopeless. In retrospect scientists should not have played this role."* (Cooperrider, 1996)

Policy debates often focus on narrow, relatively insignificant technical or scientific issues (Smith, *et al.*, 1998). For example, there are over 250 major dams in the Columbia Basin. Arguments over removal of a few dams, or the options for transporting smolts around dams, for example, are interesting and controversial technical debates, but the fact is that aquatic and terrestrial habitats *have* drastically changed in the Columbia Basin over the past few hundred years. It is highly unlikely that *wild* salmon in substantial numbers (by historical standards) can thrive in such a highly modified environment. Society may well choose to make the tradeoffs necessary to maintain a *relatively* small number of wild salmon (current levels, perhaps), but technocrats should be bluntly realistic about the actual number of wild salmon that can be expected in the face of extensive watershed alteration.

Being honest in providing scientific information also extends to full disclosure about scientific uncertainty and unknowns (Stephenson and Lane, 1995). Presenting traditional statistical expressions of uncertainty is imperative, but so is acknowledging the boundaries of scientific knowledge. Predicting the ecological consequences of policy options is often little more than enlightened conjecture, and that reality should be clearly conveyed to decision makers and the public.

Further, it is important for salmon technocrats to be honest and forthright about the assumptions used in developing and presenting scientifically-based predictions. Different predications will result from different scientists, depending in part on which, arguably valid, assumptions are used in the technical analysis. For example, in assessing the likelihood of success of salmon policy options, assumptions must be made about such future demands as those for electricity and how those demands will be met. Reasonable people differ on what are the most realistic assumptions, but the assumptions used will substantially determine the likelihood of success of most salmon policy options. It is wrong to hide these important assumptions from the users of the scientific information.

In my experience, few salmon technocrats intentionally lie, but what does the public *hear*? Much of the current salmon policy debate is over the extent to which freshwater habitat improvement and changes in oceanic conditions will stimulate a rejuvenation of wild salmon runs. Absent from the debate is the trajectory of human population growth in the United States, in general, and the Pacific Northwest, in particular. If the average annual growth rate for the past half century (1.9%) continues, the current population of 10 million (Oregon, Washington, and Idaho) will swell to 65 million in 2100 (National Research Council, 1996). By using the same extrapolation for British Columbia's human population, we might arguably forecast the human population of the Pacific Northwest to be 85 million by 2100.

Perhaps the annual growth rate of the human population will decline, but the population in the Pacific Northwest will be much larger in 2100 than it is now. Current U.S. policy *de facto* supports human population increase through relatively open immigration, even as the current reproductive rate of the American- and Canadian-born segment of the human population is below the population replacement level (Salonius, 1999). To overlook the near certain reality of a much larger human population, and the corresponding implications for the future of salmon, is misleading the public (Salonius, 1999). Improvements in salmon spawning habitat *may* have demonstrable merit for restoring wild salmon runs *if* the number of humans in the Pacific Northwest were static, but habitat improvements will be of limited use in preserving wild salmon runs if the human population increases several-fold in the next hundred years and fishing pressure (commercial, recreational, and Indian) remains high.

Salmon scientists should focus on "science" when they are providing scientific and technical information. The philosophical literature is replete with discussions of the differences between "is" and "ought" statements and whether the conduct of science is, or can ever be, value-free. The rudimentary philosophical dichotomy is that science deals with statements of fact, observation, or probability (the "is" statements), while policy advocacy deals with statements of preference (the "ought" or "should" statements). At the extreme in the salmon policy debate, the is/ought split is clear, but it becomes much hazier when the explicit tasks performed by salmon technocrats are examined.

Technocrats often subtly use "ought" statements under the appearance of "is" statements. For example, descriptors such as habitat *degradation* or *improvement* implicitly assume a desired condition for a particular species or ecosystem. Constructing a specific dam may be described as *degradation* of salmon habitat, while the same dam might also be characterized as *improving* walleye habitat. Similarly, harvesting an old growth forest and creating a meadow might *improve* habitat for white-tailed deer, but the same action would be *degrading* habitat for spotted owls and salmon.

In my experience, most technocrats will accept the premise that science deals with "*is*" issues, but many also hold strong personal policy preferences that often creep into what appear to be value-neutral science observations. Decision makers and the public need to insist that salmon technocrats remain focused on the *is* issues, the science aspects of policy.

Demanding that salmon technocrats focus on science does not constrain their activities to esoteric, policy-irrelevant science that has little influence on society's decisions on salmon policy. On the contrary, their work and professional judgments should be presented in brutally honest, direct, and understandable ways, but they should avoid advocating policy choices based on personal values or preferences (Mills and Clark, 2000).

Some among the public have criticized scientists and policy makers for creating a *de facto* "priesthood of scientists" – those ordained to pass judgment on the rights and wrongs of ecological policy (Cooperrider, 1996). We live in a society that venerates scholarly accomplishment, professional credentials, academic degrees, and professional titles. In fact, because politicians and appointed decision makers face difficult, controversial ecological policy choices, it is natural for them to use technocrats as a convenient political cover. It is inviting to shift the responsibility for an unpopular policy to salmon technocrats with their aura of credentialed respectability (Taylor, 1999).

Salmon technocrats need to be constantly on guard to avoid being drawn into the role of providing political cover for decision makers. For example, there is no *scientific* imperative for maintaining wild salmon in the Pacific Northwest even though proponents constantly offer up implicit support from scientists: "It is clear from the science what we need to do about the salmon problem." There would certainly be ethical, ecological, and social implications associated with driving wild salmon to extinction, but there is nothing in *science* that says this should or should not be done. Science is provides no help to society in adjudicating those policy debates that involve moral or philosophical elements.

No matter how much pressure there is from decision makers, salmon technocrats should not offer personal opinions about which option *should* be chosen. Decisions in salmon policy are largely based on differences in values, preferences, and priorities, not science. Scientific information has a role in decision analysis, but it is primarily to state clearly the consequences of various policy alternatives, not to lobby for any particular alternative (Stephenson and Lane, 1995).

All salmon technocrats should recognize that framing the policy question largely defines the analytical outcome (Mills and Clark, 2000). This article began with the implicit assumption that the decline of wild salmon was the primary policy issue of concern in the Pacific Northwest. It could have begun with a policy question focused on affordable housing, economic growth, family wage jobs, retirement security, social welfare, or education. Maintaining wild salmon is not *inherently* more important than the alternative societal aspirations; it is one of many competing societal aspirations. Such competing societal aspirations are not necessarily mutually exclusive, but they are linked and they do compete.

Arguments over framing the policy question are typically the most divisive part of the policy debate because framing the policy question is a political exercise, not a scientific one. Defining policy questions is value-based, although scientific information has a role in identifying plausible options and in predicting the ecological consequences of different policy alternatives.

Framing a policy question in *salmon* terms, for example, largely defines the result. In reality, the policy debate is not what should be done about wild salmon, as if it was the only policy question on the table, but rather, how important is salmon restoration compared to the competing alternatives. For example, society, in addition to "demanding" maintenance of wild salmon, "demands" personal mobility. Personal mobility means having an effective road system. North American society implicitly "demands" economic growth which is fueled, in part, by an expanding human population. Increasing numbers of people means additional roads are required, which means less good habitat for salmon, which, eventually, means less wild salmon. Thus the many small, piecemeal decisions that society makes on road construction have a negative, long-term overall effects on wild salmon.

Salmon technocrats should avoid the allure of junk science and policy babble in providing information. "Pseudo-science" often disguises political advocacy. Concepts like ecological health, ecological integrity, sustainability, and biological diversity can be used in scientifically valid ways, but they also can be used to beguile the public and politicians. Sustainability, for example, has an inherent appeal, but what does it mean? Traditionally, technocrats defined sustainability as "producing defined ecological benefits in perpetuity." Many different ecological elements are sustainable, so which are the most important? Sustainability is also possible at a variety of levels. What level of ecological yield is desired? Advocacy for "sustainability" does not really say much without a clear statement of policy preference. Further, it is tautological to argue that sustainability must *a priori* maintain ecosystems such that their capacity to produce goods and services in the future is not reduced. There is a multitude of possible goods and services, as well as a suite of sustainable levels of those goods and services, that can be provided by ecosystems.

Ecological integrity is sometimes offered as a concept that overcomes many of the limitations of ecosystem health, but it is likewise predicated on the assumption that there is some desired, preferred, or reference ecological condition. Who is to say that a pristine ecological condition is any better or worse than an agricultural system or urban environment? Also, who decides which ecosystems are to be chosen as the reference or baseline state? Intended or not, the very idea of *reference* sites implies that ecological conditions in the reference sites are somehow more desirable than those in other sites.

Technocrats involved with salmon policy and management should concede that societal values and priorities evolve and will continue to evolve. It was not many years ago that many current wildlife icons, such as cougars, bears, and wolves, were viewed as nuisances to be expunged from the land. Much of society now has a different view – a conviction that, far from being earmarked for eradication, these species ought to be tolerated, even protected from humans by the force of law and, furthermore, reintroduced into their former range. Through the mid 20^{th} century, even the revered bald eagle was subject to an aggressive predator control program in an attempt to protect salmon (Willson *et al.*, 1998). Neither the view that eagles, cougars, bears, and wolves are pests, nor the view that they are valued life forms to be protected, is "correct" scientifically, but they lead to dramatically different political positions.

Salmon technocrats today work in a different "rights culture" than did their predecessors (McEvoy, 1986). Concepts of rights have changed, often dramatically. Human rights and property rights, at least in western North America, have meanings that are distinct from those a century ago. Not surprisingly, clashes between the rights of individuals and those of the larger society are often resolved differently as society evolves.

It is certain that salmon technocrats a century from now will deal with societal values and priorities as different from today's values and priorities as today's values and preferences are different from those a century ago. None of the values in 1900, 2000, or 2100 is more "legitimate" than the others, except within the societal and ecological context existing at the time.

Society weighs policy choices in the context of prevailing values, preferences, and understanding of "facts." Even with the same scientific information (facts) and the identical condition of stocks, a salmon policy position from the beginning of the twentieth century doubtless would be different than a current policy on salmon. Relative to wild salmon, societal values and preferences, as well as scientific understanding, have all changed over the past century. Over the long run, a search for the scientifically *optimal* salmon restoration solution will be futile because of the complexity of the policy (and science) problem, along with changing societal values and preferences (McLain and Lee, 1996). The sooner that a salmon technocrat accepts this principle, the easier it will be to survive the ebb and flow of salmon policy debates.

Salmon technocrats would do well to avoid technical and scientific hubris in providing information or offering policy recommendations. A critical look at history reveals little justification for an exalted notion of the effectiveness of technocrats in salmon management or policy. Salmon technocrats once heralded hatcheries (now largely discredited) as the solution to dwindling salmon runs to the detriment of wild salmon (Cooperrider, 1996). Some championed a practice called "scientific management," (now acknowledged to be unsuccessful) which purported to be the solution to managing salmon and other natural resources sustainably (Ludwig *et al.*, 1993). Technocrats and others have also proposed such fixes as computer simulation and modeling, benefit/cost analysis, habitat improvement, complicated harvest restrictions, adaptive management, and cooperative management. All have their positive features, but none has reversed the decline of wild salmon. Based on history, today's solutions to restore runs of wild salmon will be held in disrepute by subsequent generations of salmon technocrats. Thus, salmon technocrats would do well to avoid technical and scientific hubris.

It is important to recognize that, although society generally expects salmon experts to solve, or at least identify practical options to solve the salmon problem, each of the many sides in the political debate use salmon experts and scientific "facts" to bolster its policy argument (Volkman and McConnaha, 1993).

The chronicle of the attempts by salmon experts to help resolve the salmon policy conundrum is not encouraging (Meffe, 1992; Ludwig, *et al*, 1993; Cooperrider, 1996; Buchal, 1998). For example, even though the number of fisheries scientists (and total dollars spent) trying to reverse the decline of wild salmon has increased dramatically, wild salmon numbers continue to decline. Fisheries scientists dealing with salmon issues are largely limited to "situational science" – every ecological situation appears to be a specific case and few general rules or principles exist. The few general scientific principles that do exist, although important in understanding policy options, do not go much beyond common sense.

Fisheries scientists also operate in a world of conflicting societal mandates. As Scarnecchia (1988) observed about the state of salmon management:

> *". . . most Pacific Northwest salmon plans are themeless collages – surrealistic aggregations of incongruent management goals, objectives, and actions suggestive of many value systems but truly indicative of none. Such is the end result of broadly coordinated, painstaking efforts of hundreds of managers and user-*

groups representing diverse, often incompatible, value systems – some articulated, some not."

It is also apparent that salmon policy is serious business (Lackey, 1999b). Competent scientists, whether intentionally or not, routinely become embroiled in policy debates that fundamentally revolve around clashes in values and preferences, not science. We witness the spectacle of "dueling science" – each side in the policy debate parading scientists who articulate scientific opinions that *apparently* support the preferred political position (McLain and Lee, 1996; Buchal, 1998). If a group's position is to lobby for maintaining irrigated agriculture, for example, its advocates would do well to quote scientific findings that show that use of hatcheries, not irrigation, has done the most to reduce the size of wild salmon. If a group's political interest is in maintaining fishing and the tourist industry, its proponents will often quote scientists who will attest that three-quarters of the salmon returning to the Columbia River system are hatchery-bred and, therefore, hatcheries are essential to maintaining fishing opportunities. Thus, even the same scientific "facts" can be used to "support" competing policy positions (Lackey, 1997; 1999b).

Most individuals involved in adjudicating salmon policy are not salmon technocrats. In fact, many participates have legal or political science backgrounds. From their perspective, a reasonable question is: "how should I deal with salmon technocrats in order to make best use of their expertise?" It is a perfectly reasonable query, but one not often asked and rarely answered.

First, the public should not tolerate unjustified optimism (or pessimism) from salmon technocrats. Few people like to be bearers of unpleasant news. Because the public longs for wild salmon restoration with minimum societal dislocation and economic cost, it is only natural that salmon technocrats search for the silver lining, the good news, in what otherwise would be a dismal message. My recommendation is to avoid such displacement behavior. Scientists should describe the consequences of current (and alternative) salmon policies as accurately as possible, succumbing to nether pessimism or optimism.

Second, the public should demand that salmon technocrats speak understandably. Most of the fundamental technical and scientific issues of crucial importance in salmon policy are not as difficult to understand as is often asserted. Salmon technocrats should be forced to limit esoteric scientific discussions to scientific discourse, not extend them into public policy debates.

Third, the public should recognize that the policy choices are tough and that honest salmon technocrats will not have easy, painless answers. The expectation of finding a magic solution to the declining runs of wild salmon is futile (Lichatowich, 1999).

Fourth, the public should be cautious with "scientists for rent." Scientific information and models can be made to *appear* to favor certain promulgated policy choices, or undermine those of rivals (McLain and Lee, 1996). In reality, scientific information can clearly be used to demonstrate that a particular policy option has little likelihood of success (*i.e.*, not ecologically feasible), but scientific information, in and of itself, does not inherently support *any* of the policy options that *are* ecologically feasible.

Finally, the public should be wary of salmon technocrats offering policy positions under the guise of science. Many salmon technocrats have strong personal views on the desirably of restoring wild salmon to the Pacific Northwest, but such beliefs reflect personal values and preferences, not scientifically derived conclusions. Embellishing such personal views with the language of science adds a deceiving veneer of credibility.

11. Alternative PNW Ecological Futures

In the Pacific Northwest, the most vocal public concern over salmon policy is driven by the documented decline of *wild* salmon (Smith and Steel, 1997; Lichatowich, 1999). The full extent of the decline of wild salmon is not accurately known, but public concern is real. Public concern is not limited to loss of a food or recreational resource because farm-raised (from many sources) and imported wild salmon (mainly from Alaska) are readily available for retail sale, and supplemental stocking could maintain at least some runs in perpetuity, albeit at high economic and ecological cost (Michael, 1999).

In the Pacific Northwest, many people view salmon as a cultural symbol, an indicator, however ethereal, of the region's quality of life (Lang, 1996; National Research Council, 1996). Such passion for wild salmon does not necessarily mean that these individuals are willing to favor salmon over all competing priorities (*e.g.*, flood control, inexpensive electricity, personal mobility), but it does mean that maintenance of salmon is a pivotal policy necessity for them; in fact, for some individuals, restoring wild salmon runs is a *central* public policy objective (Smith, *et al.*, 1998).

The most important single driver determining the ecological future of the Pacific Northwest is the size, character, and distribution of the region's human population (Northcote, 1996). The population of the Pacific Northwest is growing rapidly – at a rate comparable to that in some Third World countries. From the post Ice Age waves of aboriginal immigrants from the North, to the influx of North Americans (and Europeans) from the East during the past two centuries, to the deluge from California and southward after the Second World War, the Pacific Northwest has been transformed in a few thousand years from an uninhabited corner of the planet to one of the most urbanized regions of North America with nearly three-quarters of the population residing in urban communities (1990 US Census). There are other sections of North America with larger urban populations, but the Pacific Northwest also is now a region of urbanites; thus, urbanites are now a majority of the electorate. The human population surely will continue to grow in the Pacific Northwest and will probably become even more urbanized.

It is debatable whether feasible public policy options for restoring wild salmon exist in the overlap between what is ecologically *possible*, and what is *desired* by society. For most individuals, the choices are difficult, unpleasant, and preferably avoided. For example, the considerations in the salmon policy debate include: How expensive will energy be? Where will people be able to live? How will use of private and public property be prescribed? Which individuals and groups will be granted the right to fish? Will human food and energy continue to be subsidized? Will society be able to provide high paying jobs for the next generation? What personal freedoms will be sacrificed to restore wild salmon? What will society do to control the rate of human population growth in the Pacific Northwest which is driven almost entirely by immigration from outside the United States and Canada, as well as emigration to the Pacific Northwest from elsewhere in the United States and Canada? It is the answers to these and other questions that will fundamentally determine the future of wild salmon runs. Science can help evaluate the consequences of different policy options, but the salmon "problem" is an issue of *societal* choice (Smith and Steel, 1997; Lackey, 1999b).

The decline of wild salmon and other anadromous species is not confined to the Pacific Northwest (Parrish *et al.*, 1998). The demise of most salmon stocks in Europe, the Asian Far East, and the Northeastern United States is strikingly parallel to what is now happening in the Pacific Northwest. Most of the wild salmon stocks in these other areas have vanished, yet, even in those locations, no *species* of salmon currently faces extinction.

12. Restoration – Options and Illusions

Is society chasing an illusion in attempting to restore wild salmon to the Pacific Northwest, considering the near certain increase in the region's human population through the 21st century and the dramatically different habitat of the Pacific Northwest compared to what existed even a century ago (Northcote, 1996)? The Columbia Basin, for example, is now dominated by a series of mainstem and tributary reservoirs. Land use in much of the watershed has changed the aquatic environment in ways that no longer favor salmon (Bisson *et al.*, 1997; Michael, 1999). As dramatic as the environmental changes are, some fishes, especially exotics, are thriving (*e.g.*, walleye, American shad, smallmouth bass, and brook trout. These exotic species are well adapted to the new environment. From a purely ecological perspective, it would be extremely onerous to re-create the Pacific Northwest habitats that once existed and were ideal for wild salmon. Thus, a simple, cheap policy option would be to manage for those fishes best suited to *current* habitat.

There have been serious efforts to systematically prioritize salmon stocks to help allocate efficiently society's efforts to protect and restore runs (Allendorf *et al.*, 1997). A similar option is to preserve stocks in those locations, such as some "coastal" rivers, where some reasonably healthy wild stocks still exist and where the chances of restoration are greater (Michael 1999). Others argue that perhaps we should stop focusing on *stocks* and accept that no *species* of salmon is in danger of extinction. This acceptance of the "inevitable" is countered as merely admitting defeat in the face of difficult, expensive, and divisive policy choices.

The people of the United States and Canada now devote considerable resources toward earnest, and often futile, attempts to restore wild salmon stocks (Independent Scientific Group, 1999). Will society conclude that the *economic* costs of maintaining wild salmon in ecologically suboptimal environments is too high? More fundamentally, will society question and reverse, as some suggest, the economic expansionist ideology that has long been the hallmark of western society (Lichatowich, 1999; Salonius, 1999)? Michael (1999), in one of the few cases of someone directly trying to answer such questions, concluded that:

> *" . . . society has already decided that anadromous salmonids in the Pacific Northwest will exist in low numbers and less diversity than historically."*

Current and past attempts to deal with the inexorable increase in the human population of the Pacific Northwest (primarily land use planning and zoning) have not been successful (Northcote, 1996). Growth management, including the various permutations of "land use zoning," "balanced growth," "sustainable growth," "smart growth," or "environmentally sensitive growth" have merely attempted to accommodate the growth of the human population in the least disruptive way. Without a change in the "standard of living," it is a delusion to expect that wild salmon runs can be maintained, much less restored, with a doubling, tripling, or more of the region's current human population. The necessary changes in policies on human population growth rate and the associated economic reorientation would be draconian; there is little apparent willingness on the part of society to consider such choices.

I predict that through the 21st century there will continue to be appreciable year-to-year variation in the size of wild salmon runs, accompanied by the decadal trends caused by cyclic climatic and oceanic changes, but most stocks of wild salmon in the Pacific Northwest likely will remain at their current low levels or continue to decline in spite of costly restoration efforts. Based on historic patterns, another cyclic climatic and oceanic change likely will occur early in the 21st century, last several decades, and stimulate modest increases in the size of wild salmon runs generally, but the long-term trend is likely to remain downward (Hare *et al.*, 1999).

It may appear that political institutions are unable to act, but, in fact, decisions are made daily on the relative importance of maintaining or restoring *wild* salmon compared to competing societal priorities – though few people appear to be happy with the present situation, and everyone publicly professes support for maintaining salmon. Thus, it is likely that society will continue to chase the illusion that *wild* salmon runs can be restored without massive changes in the number, lifestyle, and philosophy of the human occupants of the western United States and Canada.

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Biographic Sketch

Dr. Robert T. Lackey is a natural resource ecologist with the Environmental Protection Agency's research laboratory in Corvallis, Oregon and is courtesy professor of fisheries science and adjunct professor of political science at Oregon State University. For the past 30 years he has dealt with a range of environmental issues from positions in government and academia. Among his professional interests are natural resource ecology, ecosystem management, ecological risk assessment, and the interface between science and public policy. He has written 85 scientific journal articles, a book on fisheries science, as well as editing three others. Dr. Lackey also has long been active in education, having taught natural resources and environmental management at five universities. He continues to regularly teach a graduate course in ecological policy at Oregon State University. He was a 1999-2000 Fulbright Scholar at the University of Northern British Columbia.

Table 1. Estimated historic (*late 1800s*) and current run sizes (*late 1900s*) of wild salmon in western North America (modified from Gresh, *et al.*, 2000). (All numbers in millions of wild salmon; numbers are rounded)

Area	**Historic Run Size**	**Current Run Size**
Alaska	150-200	115-259
British Columbia	44-93	24.8
Puget Sound	13-27	1.6
Washington Coast	2-6	.07
Columbia Basin	11-15	.11-.33
Oregon Coast	2-4	.10-.32
California	5-6	.28
TOTAL	227-352	142-287