Salmon Policy:

Science, Society, Restoration, and Reality

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Abstract

Salmon policy in the Pacific Northwest illustrates a class of contentious, socially wrenching issues that are becoming increasingly common in the western United States as demands increase for limited ecological resources. Many Pacific salmon "stocks" (a term used in fisheries management for a group of interbreeding individuals that is roughly equivalent to "population") have declined and some have been extirpated. The salmon "problem" is one of the most vexing public policy challenges in natural resource management. Even with complete scientific knowledge — and scientific knowledge is far from complete or certain — it would be a challenging policy problem. The salmon decline issue is often defined simplistically as a watershed management problem, in part because changes in watersheds are highly visible and often occur on public or corporate lands where individuals and organizations often have direct input to decision making. Yet, changes in climate and ocean conditions, for example, occur frequently and such changes have a major influence on salmon abundance. The scientific challenges are great, but the more difficult — and critical — aspect of the debate concerns policies and decisions affecting everyone, including those involved in rural enterprises (especially farming and logging); manufacturing and construction; electricity generation (including hydro, fossil fuel, and nuclear); national defense; urban development; transportation (including road, rail, air, and water). The debate also involves competing personal rights and freedoms; the prerogatives and roles of local, state, and federal government and Indian tribes; policies on human population level, reproduction, emigration, and immigration; and the future of fishing (commercial, recreational, and Indian). The salmon policy conundrum is characterized by: (1) nearly everyone claims to support maintaining wild salmon runs; (2) many competing societal priorities exist, many of which are partially or wholly mutually exclusive; (3) the region's rapidly growing human population creates increasing pressures on all natural resources (including salmon and their habitats); (4) policy stances in the salmon debate are solidly entrenched; (5) society expects salmon experts to help solve the salmon problem; (6) each of the many sides of the political debate over the future of salmon use salmon experts and scientific "facts" to bolster its argument; (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. Although far from indisputable, I conclude that over the next century and allowing for considerable year-to-year and decade-to-decade variation, 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 costly protection and restoration efforts.

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[1] The views and opinions expressed do not necessarily represent those of any organization.

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1. Introduction

Many populations of Pacific salmon on the west coast of North America are declining (Netboy, 1980; Cone and Ridlington, 1996; National Research Council, 1996). 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). Public institutions seem to be unable to act in a way to protect or restore wild salmon runs (Lee, 1993). Virtually no one is happy with the present situation, yet few recognize the connections between individual and societal choices and the status of salmon. Thus, there is a policy conundrum: salmon ostensibly enjoy universal public support, but society is, or at least has been, unwilling to arrest their decline (McGinnis, 1994, 1995).

Salmon policy illustrates a class of contentious, socially wrenching issues that are becoming increasingly common in the western United States as demands increase for limited ecological resources (Lackey, 1997). These 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; (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 damaged, and these tradeoffs are well known; (4) *delayed consequences* — there is no immediate "fix," and the benefits, if any, of painful decisions 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 the choice of an option because the choice 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 a myriad of interest groups, each of which has a vested interest in the outcome of the policy debate and often vigorously articulate “science” that supports its policy position.

The salmon policy conundrum is described by a series of observations: (1) nearly everyone claims, at least at a superficial level, to support maintaining wild salmon runs (Smith and Steel, 1996); (2) many competing societal priorities exist, many of which are partially or wholly mutually exclusive; (3) the region’s rapidly growing human population creates increasing pressures on all natural resources (including salmon and their habitats); (4) policy stances in the salmon debate are solidly entrenched; (5) society expects salmon experts to help solve the salmon problem; (6) each of the many sides of the political debate over the future of salmon use salmon experts and scientific “facts” to bolster its argument; (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, 1999).

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). Yet, choices are being made — even the "no action" option is a policy choice. They may not be the best choices (*best* defined here as the desires of the majority being implemented without unexpected consequences), but choices are being made.

My purpose is to describe the current situation in salmon policy within an historical and societal context. Most debate in salmon policy is fundamentally a clash between competing values and preferences, but a certain amount of scientific information is required to appreciate the policy issues. Unfortunately, it is easy to be needlessly diverted by biological and science discussions because they reflect the training and comfort zone of most us who are salmon technocrats, but such diversions mask the necessary dialog about which societal values will adopted. Therefore, I will constrain the description of the state of scientific knowledge to that required to scrutinize salmon policy.

Throughout this paper, I have attempted to be policy *relevant*, but not to advocate for any policy option. There is no course of action for society to select that will reverse the apparent decline of wild salmon that is not socially disruptive and economically expensive.

2. Salmon Biology

There are seven species of what are often called "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) on the North American side. There are also two species of sea running trout (rainbow and cutthroat) that have very similar life histories and are often classified together with the seven true salmon and treated as "Pacific salmon." In contrast to true Pacific salmon, not all sea running trout die after spawning (Pearcy, 1992). Because sea running trout and true Pacific salmon have similar life cycles, I will group them all as *Pacific salmon*. Several species of Pacific salmon have been introduced elsewhere (*e.g.*, the Great Lakes, New Zealand, and Norway) and have established migratory populations, but these are not considered here.

Pacific salmon are native to California, Oregon, Washington, Idaho, Montana, British Columbia, Yukon, Alaska, the Russian Far East, Korea, China, and Japan (Groot and Margolis, 1991). At certain periods in history, they were even found in Baja California and, until very recently, Nevada. Their overall distribution has varied over the last several thousand years, mostly caused by climatic shifts, but the *approximate* distribution has been relatively constant. Prior to 4,000 years ago, however, the distribution of Pacific salmon was much restricted by the residual effects of the last ice age.

Pacific salmon are *anadromous* — that is, they spawn in freshwater and, a few weeks 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 relatively slow if the *number* of salmon is low, requiring from decades to centuries for salmon to occupy empty habitats.

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, 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.

Salmon species are composed of *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*., 1996). Debate over the "extinction" of wild salmon is usually focused on decline or loss of salmon *stocks*, not salmon *species*. Many stocks of salmon have been extirpated, but it is extremely unlikely that any *species* of salmon will disappear in the foreseeable future.

3. Salmon Trends

Even though the general trajectory of total salmon numbers is downward in the Pacific Northwest, assessing the extent of the decline is difficult — even determining the number of stocks is challenging (National Research Council, 1996).

The number of salmon stocks in the Pacific Northwest is not known, both because of lack of data and scientific debates about the level of genetic distinctiveness required to define a stock. The number of stocks is in the several thousand range, perhaps 5,000 - 15,000. Defining a stock is far from simply a scientific exercise; it has major policy ramifications in the United States because a "stock" may be considered a "species" under government and court interpretations of the U.S. Endangered Species Act.

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. The concept of "evolutionarily significant unit" (ESU) was created to describe a salmon "population" whose loss would be significant for the genetic or ecological diversity of salmon species (Mundy *et al*., 1995). 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 fundamental premise that it is possible to judge the evolutionary significance of one spawning aggregate against that of another (Mundy *et al*., 1995).

Beyond concerns about the effect of declining salmon runs on genetic diversity, there is the less obvious role salmon play in providing nutrients to watersheds, particularly the upper portions of watersheds. 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.

Over 200 salmon stocks in California, Oregon, Idaho, and Washington (Nehlsen *et al*., 1991) and over 867 in British Columbia and Yukon (Slaney *et al*., 1996) are at high risk; that is, extinction is likely unless something changes rapidly. Some stocks, perhaps 100-200, are already extinct. Even allowing for considerable scientific debate 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 decline is 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 found in many smaller rivers along the coast. Causes of the declines are numerous and vary by geography, species, and stock; there are no universal corrective action that will reverse the declines.

In California — the most southern part of the current range of salmon — since 1980, virtually all salmon stocks have declined to record or near-record low numbers (Mills *et al.*, 1996). Another survey concluded that most California salmon stocks are extinct or unhealthy (Huntington *et al.*, 1996).

In Oregon, although there is considerable disagreement on specific stocks, the general status of salmon stocks is mixed (Kostow, 1996). 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.

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*., 1996). Coastal and Puget Sound stocks were generally in better condition than were those occupying the Columbia watershed. Another, independent survey, however, found only 99 healthy (defined as at least one third the run size that would be expected without human influence) throughout the *entire* Pacific Northwest (Huntington *et al*., 1996).

Not surprisingly, wild salmon have declined markedly in Idaho. 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. The decline has been especially sharp during the last three decades (Hassemer *et al.*, 1996).

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

Alaska now produces approximately 80% of the wild salmon harvested in North America (Wertheimer, 1996). 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). 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 and 1998 (Kruse, 1998).

The size of salmon runs varies 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, 1996; Hare *et al.*, 1999). This reciprocal relationship appears to be driven by oscillating climatic conditions, the resultant effect on ocean currents and upwelling that support salmon food supplies, and the subsequent consequences for salmon during the ocean phase of their life cycles. As ocean currents shift, often abruptly, marine habitat that was ideal for salmon can rapidly become inferior. The north-south dominance cycle appears to repeat every 20-30 years (Hare *et al.*, 1999).

Aquaculture, growing fish in captivity, is well developed for salmon and trout. Thus, it is fairly easy to raise salmon in captivity and provide a steady supply to markets. As a result, salmon are inexpensive by historic standards and are readily available. Commercial quantities of salmon are grown in captivity in the Pacific Northwest, Scandinavia, Scotland, and Chile and provide markets with a constant supply of fresh salmon.

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

4. Historical Perspective

Knowing the extent and size of historical salmon runs in the Pacific Northwest is important because these data provide the basis to measure the current state of wild salmon stocks. There is a natural tendency to use the early and mid 1800s as the baseline; explorers and settlers reported massive salmon runs that became the implicit benchmark for comparing the size of subsequent runs. 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 harvest of salmon increased over the past 4,000 years, probably reaching a level to affect runs in some rivers, especially toward the southern and eastern part of the salmon distribution (Swezey and Heizer, 1977). There was undoubtedly a rough equilibrium between salmon and human population levels because the number of salmon that could be harvested was limited by lack of efficient (at least in most locations) fishing gear; inability to preserve, store, and distribute the catch on a large scale; and foremost, a relatively stable 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 typical effect on salmon runs was low by current standards (Schalk, 1986). Further, except for using fire to clear vegetation, aboriginals lacked the capability to greatly affect salmon habitat. In summary, from roughly 4,000 years ago to approximately the 1500s, salmon runs likely fluctuated greatly, but the long-term trend was upward with runs likely reaching their highest levels within the past few centuries.

The 1500s marked a dramatic change in the 4,000 year history of the salmon/human relationship. 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); this human population reduction thereby may have caused a significant decline in fishing pressure. Thus, large salmon runs observed in the early to mid-1800s may have been a reflection of a long-term trend toward improved continental environmental conditions for salmon, and a decrease in fishing pressure.

5. Causes of the Decline

Conditions for salmon in the Pacific Northwest began changing markedly starting in the mid to late 1800s (Netboy, 1980; Mundy, 1996; Robbins, 1996). Starting in the middle 1800s, the human population of the Pacific Northwest ceased declining, and began growing slowly because of immigration from eastern North America. This growth coincided with the advent of more efficient fishing methods and the ability to efficiently preserve and distribute the catch in cans. Also, the timing and approximate size of the annual salmon was predictable, thus fishermen, canners, and distributors could plan accordingly. The effect on many salmon stocks was massive and rapid, but reconstructing run sizes is complicated by the observation that relatively low rates of salmon harvest will result in higher net reproduction, thus *larger* subsequent runs (Chapman, 1986). Regardless, by 1900 many stocks were reduced below levels required to ensure reproductive success, let alone support fishing; some probably were extirpated. Competition for salmon harvest has been severe throughout the 20th century; recreational, commercial, and Indian fishermen demanded a portion of a dwindling catch and successfully pressured fisheries managers to maintain relatively high catch levels. State fish and wildlife agencies, supported largely by the sale of fishing and hunting licenses, have an understandable interest in maintaining fishing opportunities (Volkman and McConnaha, 1993). The general pattern of rapidly increasing harvest and eventual over exploitation of Pacific Northwest salmon, far from being an aberration, is typical in renewable natural resource management (Hilborn *et al.*, 1995).

High harvest rates are not the only major cause of salmon decline. Dams have been 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. Dams impede passage of returning spawners and migrating young fish. Moving salmon past dams has long been a challenge to fisheries managers. Some dams totally block salmon migration. In the Columbia Basin, for example, over a third of the habitat formerly occupied by salmon is now blocked by dams. Further, dams also alter the quantity and timing of water flow and sediment transport, causing a number of ecological changes potentially adverse to salmon.

Salmon runs have dwindled as other changes took place (Cone and Ridlington, 1996). Because most of the Pacific Northwest is arid, and irrigation is necessary for farming, water diversions (and dams) for irrigation, coupled with wide-scale use of chemical fertilizers and pesticides, have contributed to reductions in salmon runs. In the Columbia Basin, for example, approximately a third of the annual flow is used for irrigation. Cattle and sheep grazing (and many other agricultural practices) can reduce salmon runs by altering water quality and spawning and nursery habitat, especially if the run size is already small (Mundy, 1996).

Timber in the Pacific Northwest is of high commercial quality (especially west of the Cascade Mountains) and there has been considerable economic incentive to use this natural resource. The harvest and transport (initially via water and later by an extensive system of forest roads) of timber has also had adverse consequences on salmon spawning and rearing. Logging and associated road construction (especially prior to widespread adoption of current best practices) may 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. Fisheries management has historically focused on hatcheries to mitigate loss (typically caused by dams) of salmon habitat. As was hoped, 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). 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."

Since the late 1800s, when hatcheries were first used to help enhance salmon stocks, attitudes have evolved from near universal support to widespread skepticism as more people became concerned with preserving *wild* salmon rather than simply maintaining runs (Bottom, 1996). 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.

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, 1996). Once released, 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 to permit fishing for hatchery fish, concurrently protect wild fish, and maintain high exploitation rates. 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."

One especially troublesome development (from a salmon's perspective) has been the introduction of non-native fishes (exotics) such as walleye, striped bass, shad, brown trout, brook trout, smallmouth and largemouth bass, bluegill, northern pike, crappie, catfish, and carp (Fresh, 1996). As salmon habitats were altered and runs declined, other fishes prospered. Once these other fishes establish thriving populations, it is extremely difficult for salmon to reestablish viable runs against such formidable competition, coupled with an altered habitat no longer favorable to salmon. Further, agencies often actively manage in favor of popular, exotic game species and indirectly hinder recovery of wild salmon.

To fully understand the decline of salmon, the open ocean and coastal portion of their life-cycles must also be considered (Pearcy, 1996). Most salmon spend the majority of their life in the ocean, not in freshwater environments. 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 correspond with trends in salmon run size (Hare *et al.*, 1999). On shorter time scales, El Niño and La Niña events may have detrimental or favorable effects on salmon. 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*., 1996).

Climatic variations and change also affect the condition of salmon stocks (Pearcy, 1996; Pulwarty and Redmond, 1997). As with oceanic variations, the type and extent of ecological effects caused by climate variations 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. The past three decades in the Pacific Northwest have been among the warmest and driest for hundreds of years. If future climatic change (natural or human induced) causes even more adverse conditions, then additional sections of the current range of Pacific salmon likely will be occupied by fishes better adapted to these altered habitats, thus causing additional downward pressure on remaining salmon stocks.

Predation, especially by marine mammals, birds, and northern squawfish, are often identified as causes of the decline of salmon in the Pacific Northwest. For example, since the early 1970s the population of harbor seals and California sea lions have increased to near historical levels because harvest of these animals has been prohibited by U.S. and Canadian law (Fresh, 1996). Because these animals congregate at river mouths, they are be very effective in capturing returning salmon (National Research Council, 1996). Marine mammals can have significant local effects on salmon runs, but they are not believed to be one of the dominant causes of the general decline of wild salmon stocks (Fresh, 1996). 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 tends to congregate in large nesting colonies, have become well established on the lower Columbia and have become 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. The Policy Conundrum

In the Pacific Northwest, the most vocal public concern over salmon policy is driven by the documented decline of *wild* salmon (Smith and Steel, 1996). The extent of the decline is not accurately known, but the decline and public concern are real. Public concern is not limited to loss of a food or recreational resource because farm-raised and imported wild salmon are readily available for sale, and supplemental stocking could maintain at least some runs in perpetuity, albeit at high economic and ecological cost.

Many people view salmon as a cultural symbol and deem further reduction of remnant wild runs as an indicator of a grave decline in the quality of life in the Pacific Northwest (Lang, 1996; National Research Council, 1996). Such passion for salmon does not necessarily mean that advocates are unwilling to trade salmon for competing priorities, but it does mean that maintenance of salmon is a pivotal policy for them; in fact, for some individuals, restoring wild salmon runs is a central public policy objective.

Developing a widely supported policy on reversing the salmon decline is a conundrum. It is apparent that maintaining salmon runs commands widespread public support (Smith and Steel, 1996), but it is also clear that there are many competing societal priorities, many of which are in conflict with maintaining salmon runs. Further, the burgeoning number of people in the region creates increasing pressures on all natural resources (including salmon), but political stances in the salmon debate are entrenched. Society generally expects salmon experts to solve, or at least identify practical options to solve, the salmon problem. However, each of the many sides of 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; 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 is 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, 1999). 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 scientists" — each side in the policy debate parading scientists who articulate scientific opinions that *apparently* support the preferred political position (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; 1999).

7. Endangered Species Issues

Recently salmon policy in the Pacific Northwest has been dominated by spirited debate over implementing the U.S. Endangered Species Act by listing individual or groups of stocks (*e.g.*, ESUs) as threatened or endangered. Some (*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 surrounding threatened and endangered species issues, making it difficult to discuss them without becoming mired in the pro and con of various policy choices. To some, the debate over endangered species is simply a matter of choosing among options, much as we do with choices over energy, transportation, or international trade policies. Resolution is achieved by following the classic political process of coming to agreement by compromise and tradeoff.

Others view endangered species 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 species 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 interpretation of when a public policy action constitutes a "taking" of private property and financial compensation to the owner is required. From one perspective, society may legitimately conclude that preservation of salmon is important, but regulations to achieve this societal objective should not unfairly burden only certain members of society. In short, the practical argument is usually that no one *de facto* should be required to 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 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.

A common assertion is that members of the U.S. Congress (and the public) really did not understand the policy implications of the Endangered Species Act when it was being debated. Much of the discussion in Congress dealt with the bald eagle, the nation's symbol, and other charismatic megafauna. Were the policy implications of the Act grasped in these debates? Were the scientific and technical difficulties credibly considered? Some skeptics question how democratic institutions are to choose among the options when the losers lose so much and there is little societal consensus except at the most general level. Others assert that we have *de facto* accepted the view of those, probably a minority view, 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 controversial concept of evolutionarily significant units, whatever those might be? Are critics correct in asserting that the Act is doomed to failure when 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, at least to date, 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.

Laws such as the Endangered Species Act are tools to help implement public policy, so it is important to determine the *de facto* public policy with regard to the decline of wild salmon. Supporters of invoking the Endangered Species Act usually insist that the Act forces society to make necessary, though painful, trade-offs. The Act may not be perfect, they usually accede, but it is needed now more than ever, as the decline of wild Pacific salmon epitomizes. If any revision of the Act is needed, they argue, it ought to be broadened to protect ecosystems and habitat, provide for earlier intervention, and focus not simply on species or subspecies already in perilous condition (Rohlf, 1991). 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, or other 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. 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 precipitated by a combination of hunting, climate change, and possibly introduced diseases (Pielou, 1991). True enough, species extinction is nothing new in the Pacific Northwest, but it is the rate and scale that are the issue today. To provide historical perspective on the biological changes that have taken place, salmon gene pools (stocks) that survived Pleistocene glaciation have been eradicated within a few human generations. Only catastrophic Pacific Northwest events such as major volcanic eruptions, massive earthquakes, and extreme climatic events such as droughts are comparable.

The human population of the Pacific Northwest is growing rapidly — at a rate comparable to those in some Third World countries. From the successive waves of aboriginal immigration from the North, to the influx of Americans from the East in the past two centuries, to the deluge from California 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 the most urbanized section of the United States with more than 60% of the population residing in urban/suburban communities. There are other sections of the United States with larger urban populations, but the Pacific Northwest 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.

Are we are chasing an illusion in attempting to restore salmon? The habitat of the Pacific Northwest is dramatically different than it was even a few hundred years ago. The Columbia Basin, for example, is now dominated by a series of mainstem and tributary lakes. Land use in much of the watershed has changed the aquatic environment in ways that no longer favor salmon (Bisson *et al*., 1996). As dramatic as the changes are, some fishes, especially exotics, are thriving: walleye, shad, smallmouth bass, and brook trout to name a few. These exotic species are well adapted to the new environment. From an ecological perspective, skeptics of restoration argue, we are surely past the stage where we can re-create past salmon habitats and a simple, cheap 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 the chances of restoration are greater. Or, as others argue, perhaps we should stop focusing on *stocks* and accept that no *species* of salmon is in danger of extinction. Others counter by denouncing such acceptance of "reality" as merely admitting defeat in the face of difficult, expensive, and divisive policy choices.

8. The Future

Public policy is created by choosing explicitly or implicitly from among options. Society's choices in the salmon policy debate include: How expensive will our energy be? Where will we be able to live? How will we use private and public property? Which individuals and groups will be granted the right to fish? Will our food and energy continue to be subsidized? Will we be able to provide jobs for our children? What personal freedoms, if any, will we sacrifice? What, if anything, will we do to control the increase the human population in the Pacific Northwest? It is the answers to these and other questions that fundamentally determine the future of wild salmon stocks. Science can help evaluate the consequences of different policy options, but the salmon "problem" is an issue of *public* choice (Smith and Steel, 1996; Lackey, 1999).

Confronting the decline of salmon runs is not new: the demise of most salmon stocks in Europe, the Asian Far East, and the Northeastern United States are strikingly parallel to what is now happening in the Pacific Northwest. Most of the wild salmon stocks in these other areas have vanished, yet no *species* of salmon currently faces extinction.

The people of the United States and Canada now earmark considerable resources toward an earnest, perhaps futile, attempt to restore wild salmon stocks (Independent Scientific Group, 1999). Unfortunately, many existing aquatic environments are much altered and not now well suited to supporting wild salmon. In many places, for example, wild stocks of Pacific salmon have been supplanted by fish species better adapted to the current aquatic environment, and it may not be possible, realistically, to maintain, much less restore, wild salmon runs. Will society conclude that the *economic* costs of maintaining wild salmon in ecologically suboptimal environments is too high? Will society be willing to bear the great *social* dislocations required to maintain wild salmon runs?

Although far from indisputable, I conclude that over a multiple decadal time scale and allowing for considerable year-to-year and decade-to-decade variation, there is little doubt that many, perhaps most, stocks of wild salmon in the Pacific Northwest will remain at their current low levels or continue to decline in spite of current costly protection and restoration efforts. 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, they are making decisions on the relative importance of maintaining 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, the apparent policy conundrum continues: salmon enjoy near universal public support, but society is apparently unwilling to arrest their decline.

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